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SCHOOL OF MINES QUARTERLY.

INDEX, VOL. XXI.

November, 1899, to July, 1900.

All Abstracts are printed in Italics, and those relating to Metallurgy or to Chemical Analysis appear only under the heading Analytical Chemistry.

Alternating Current Distribution, Principles of. By F. B. Crocker..... 93
Alternating Currents, Asymmetrical, by Means of Electrolytic Polarization, On the Production of. By W. L. Hildburgh..... 358

ALUMNI AND UNIVERSITY NEWS.

Alumni of the Schools of Science, Constitution. Apx..... 133
Alumni of the Schools of Science, Lists of. Apx..... 1
Architecture..... 88, 194
Chemistry..... 86
Columbia University Chemical Society..... 90, 195
Electrical Engineering..... 89
Geology..... 87
Metallurgy..... 86, 195
Summer School of Mining..... 84
Thomas Egleston Minute..... 292

Amalgam Plates, see Plates.
Analytical Chemistry, Abstracts. By Elwyn Waller.

Action of Stannous Chloride on Lead Salts..... 77
Alkalies in Waters..... 278
Alkalimetric Indicators..... 75
Alkaline Glassware..... 75
Alumina-Direct Precipitation..... 278
Analyses of Tungsten Compounds..... 282
Analysis of Dynamite, etc...... 82
Analysis of Stibnite..... 77
Arsenic in Paris Green..... 280
Ash..... 286

Boric Acid Test..... 81
Brass Analysis..... 282

Calcium Carbonate in Soil and Marls..... 80
Carbon Combustion in Platinum Crucible..... 79
Carbon Monoxide Estimation..... 80
Carbon, Volumetric..... 80
Carbonate in Soils..... 80
Chlorates, Bromates and Iodates..... 284

Chloride in Small Amounts in KBr 283
Chromium in Steel 279
Coal Analysis 286
Cobalt in Presence of Iron 279
Commercial Copper 281

Decomposition of Silicates by Boric Acid 79
Delicate Test for Stannous Chloride 280
Determination of Bismuth 77
Distinguishing Ozone from Hydrogen Peroxide, or Nitrous Acid 82

Electrolytic Separation of Cadmium from Iron 76
Electrolytic Separation of the Halogens 77
Estimating Aluminium 279
Estimating Thallium as Chromate 282
Estimation of Formic-Aldehyde 81
Explosions 83

Gelatine Dynamite 82
Graphitic Carbon in Irons 285

Indicators for Alkalimetry 277
Iodic Acid in Commercial Nitrate of Soda 283
Iodine in Presence of Bromine 78

Kjeldahl Process for Nitrogen 285

Moisture 286

Nickel in Steel-Colorimetric 76
Nickel in its Ores 280
Nitric Acid in Water 285
Nitrogen in Fertilizers 285

Oxygen in Copper 76

Parting of Gold-Platinum Alloy 281
Pearce's Method for Arsenic Modified 77
Phosphine in Acetylene 79
Potassium Estimation 278
Precipitation of Nickel by Ammonia 280

Removing Lime and Magnesia from Waters 83

Selenious Acid Titration 78
Separation of Arsenic, Antimony and Tin 280
Separation of Cerite Metals 77
Separation of Chloride from Iodide 283
Separation of Gold from Platinum 281
Separation by HCl Gas 75
Silicon in Ferro-Chromium or Silica in Chromite 285
Silver Bullion 281
Silver in Plated Copper Articles 282
Solution of Ignited Ferric Oxide 279
Stability of Standard Oxalic Acid Solution 75
Standardizing Alkalimetric and Acidimetric Solutions 277
Standardizing Alkalimetric Solutions 277
Sulphur 286
Sulphur in Coal 284
Sulphur in Pig Iron 284
Sulphur in Pyrites 284
Sulphydric, Sulphurous and Hypo-Sulphurous Compounds 284

Use of Hydrogen Peroxide 277

Very Sensitive Litmus Paper 75
Victorium. A New Element 83
Volatile Combustible 286

Volumetric for Boric Acid..... 81
Volumetric for Carbon..... 79
Volumetric for Magnesia..... 278
Volumetric for Magnesium..... 278
Volumetric for Nickel.....76, 280
Volumetric for Sulphur in Irons..... 284
Volumetric for Zinc..... 279

"Weissmetal"—Alloy of Lead, Tin and Antimony..... 282

Zinc in Dried Apples, etc..... 279

ANDREWS and MURDOCH. *Current Mining Cases, Abstracts*.....286, 398
Architectural Practice, The Course in. By C. P. Warren..... 337
Assay Practice of the West Compared with that of the School of Mines. By Charles Fulton..... 394
BLÖMEKE, C. *The Progress in Ore Dressing*. Translated by Charles Fulton. 28, 137, 239
BOOK REVIEWS:
Calculations of Analytical Chemistry. By Edmund H. Miller..... 407
Éléments de Paléobotanique. By R. Zeiller..... 298
Hints on Amalgamation, and the general care of Gold Mills. By W. J. Adams..... 92
Manual of Practical Assaying. By H. Van F. Furman..... 296
Ore Deposits of the United States and Canada. By J. F. Kemp..... 293
Practical Course in Mechanical Drawing. By William Fox and C. W. Thomas..... 297
Primer of the Calcus. By E. S. Gould..... 92
Qualitative Chemical Analysis. By A. H. Elliott and G. A. Ferguson..... 297
Steam Engine Theory and Practice. By William Ripper..... 296
Text-Book of Physics. By W. Waston..... 408
Brief Review of the Titaniferous Magnetites. By. J. F. Kemp..... 56
Carbonyls, Metallic, and their decompositions, A Study on. By H. A. Loos and Victor Lenher..... 182
CLARK, ALLAN JAY. *Silver Plating of Amalgam Plates for Gold Mills*..... 48
Conductors, Preliminary Tests on the Properties of, with Engineering Tests on Direct Current Electrical Machinery. By G. F. Sever.....113, 218
Conflict Between Sir Isaac Newton and the French School of Astronomers Concerning the Figure of the Earth. By D. H. Pollard..... 350
Course in Architectural Practice. By C. P. Warren..... 337
CROCKER, FRANCIS B. *Principles of Alternating Current Distribution*..... 93
CURRENT MINING CASES, Abstracts. By Andrews and Murdoch.....286, 398
Currents, see Alternating Currents.
DENNEY, G. A. *Some Notes on the Mining Practice of the Witwatersrand Gold Fields, South African Republic*..... 1
Earth, Figure of, Conflict Between Sir Isaac Newton and the French School of Astronomers Concerning the. By D. H. Pollard..... 350
Egleston, Professor Thomas. By A. J. Moses..... 197
Egleston, Professor Thomas, Bibliography. By A. J. Moses..... 214
Electrolytic Polarization, On the Production of Asymmetrical Alternating Currents by Means of. By W. L. Hildburgh..... 358
Engineering Tests on Direct Current Electrical Machinery with Preliminary Tests on the Properties of Conductors. By G. F. Sever.....113, 218
Engines, see Heat Engines.
Ferrocyanide Titration of Zinc, Notes on. By E. H. Miller and E. J. Hall..... 267
FULTON, CHARLES. *The Assay Practice of the West Compared with that of the School of Mines*..... 394
FULTON, CHARLES, Translator. *The Progress of Ore Dressing*. By C. Blömeke.....28, 137, 239
Gold Fields, see Witwatersrand Gold Fields.

HALL, E. J. and MILLER, E. H. *Notes on the Ferrocyanide Titration of Zinc*.. 267
HAMLIN, A. D. F. *The Paradox of the Pantheon*, II–III.....170, 261
Heat Engines, Mean Effective Temperature a Unit of Comparison for. By C. E. Lucke 382
HILDBURGH, WALTER LEO. *On the Production of Asymmetrical Alternating Currents by Means of Electrolytic Polarization*..... 358
KEMP, J. F. *A Brief Review of the Titaniferous Magnetites*..... 56
LEHNER, VICTOR. See Loos, Hermann and Lehner, Victor.
LOOS, HERMAN A. and LEHNER VICTOR. *A Study on the Metallic Carbonyls and their Decompositions*..... 182
LUCKE, CHARLES E. *Mean Effective Temperature a Unit of Comparison for Heat Engines*..... 382
Magnetites, Titaniferous, A Brief Review of. By J. F. Kemp..... 56
Mean Effective Temperature a Unit of Comparison for Heat Engines. By C. E. Lucke 382
MILLER, EDMUND H. and HALL, E. J. *Notes on the Ferrocyanide Titration of Zinc*..... 267
Minerals, Common or Economically Important, Simple Tables for the Determination of. By A. J. Moses..... 192
MINING CASES, CURRENT, ABSTRACTS. By Andrews and Murdoch.....286, 398
MOSES, ALFRED J. *Professor Thomas Egleston*..... 197
MOSES, ALFRED J. *Professor Thomas Egleston, Bibliography*..... 214
MOSES, ALFRED J. *Simple Tables for the Determination of the Common or Economically Important Minerals*..... 192
MURDOCH and ANDREWS. See Andrews and Murdoch.
Notes on the Ferrocyanide Titration of Zinc. By E. H. Miller and E. J. Hall... 267
OBITUARY.
Egleston, Prof. Thomas. By A. J. Moses 197
Watson, Frederick Morgan. By Robert Peele..... 273
On the Production of Asymmetrical Alternating Currents by Means of Electrolytic Polarization. By W. L. Hildburgh..... 358
Ore Dressing, Progress in. By C. Blömeke. Translated by Charles Fulton. 28, 137, 239
Paradox of the Pantheon. II–III. By A. D. F. Hamlin 170, 261
Peele, Robert. Frederick Morgan Watson..... 273
Plates, Amalgam, for Gold Mills, Silver Plating of. By A. J. Clark 48
Polarization, see Electrolytic Polarization.
POLLARD, D. H. *The Conflict Between Sir Isaac Newton and the French School of Astronomers Concerning the Figure of the Earth*..... 350
Principles of Alternating Current Distribution. By F. B. Crocker..... 93
Progress in Ore Dressing. By C. Blömeke. Translated by Charles Fulton. 28, 137, 239
Question of Temperature-Influence on the Specific Rotation of Sucrose. By F. G. Wiechmann 299
Reduction-Roasting—Its Value for Arsenic-Expulsion from Copper Ores and Mattes. By E. W. Scherr, Jr..... 66
Scherr, Emilius W., Jr. Reduction-Roasting—Its Value for Arsenic-Expulsion from Copper Ores and Mattes..... 66
SEVER, GEORGE F. *Engineering Tests on Direct Current Electrical Machinery with Preliminary Tests on the Properties of Conductors* 113, 218
Silver Plating of Amalgam Plates for Gold Mills. By A. J. Clark 48
Simple Tables for the Determination of the Common or Economically Important Minerals. By A. J. Moses..... 192
Some Notes on the Mining Practice of the Witwatersrand Gold Fields, South African Republic. By G. A. Denny..... 1
Study of the Metallic Carbonyls and their Decompositions. By H. A. Loos and Victor Lenher..... 182

Temperature-Influence on the Specific Rotation of Sucrose, The Question of. By F. G. Wiechmann 299
Titaniferous Magnetites, see Magnetites.
Titration, see Ferrocyanide Titration.
WALLER, ELWYN. *Analytical Chemistry, Abstracts* 75, 277
WARREN, C. P. *The Course in Architectural Practice* 337
Watson, Frederick Morgan. By Robert Peele 273
WIECHMANN, FERDINAND G. *The Question of Temperature-Influence on the Specific Rotation of Sucrose* 299
Witwatersrand Gold Fields, South African Republic, Some Notes on the Mining Practice of. By G. A. Denny 1
Zinc, Notes on the Ferrocyanide Titration of. By E. H. Miller and E. J. Hall.. 267

VOL. XXI. No. 1. NOVEMBER, 1899.

JAN 3 1900

SCHOOL OF MINES QUARTERLY.

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CONTENTS:

Some Notes on the Mining Practice of the Witwatersrand Goldfields, South African Republic. By G. A. Denny..... 1

The Progress in Ore Dressing. By C. Blömeke..... 28

The Silver Plating of Amalgam Plates for Gold Mills. By Allan Jay Clark, E.M..... 48

A Brief Review of the Titaniferous Magnetites. By J. F. Kemp..... 56

Reduction—Roasting—Its Value for Arsenic Expulsion from Copper Ores and Mattes. By Emilius W. Scherr, Jr., A. M..... 66

Abstracts in Analytical Chemistry. By Elwyn Waller..... 75

Alumni and University News..... 84

Book Reviews..... 92

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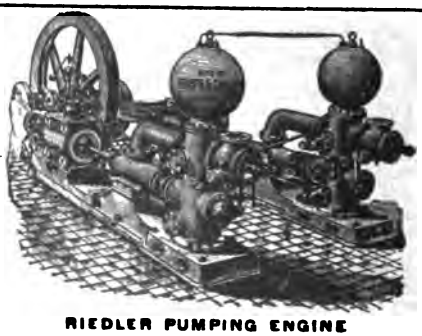

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SOME NOTES ON THE MINING PRACTICE OF THE WITWATERSRAND GOLD FIELDS, SOUTH AFRICAN REPUBLIC.

BY G. A. DENNY.

(Continued from Page 378, Vol. XX.)

Deep Level Properties.—These form an entirely separate group from the outcrop mines. The systems of mining are almost similar, but the methods of attack naturally differ inasmuch as the reefs enter the boundaries of the properties at depths ranging from 1,000 to 3,000 feet. The question of the location of the shafts for the best exploitation of the properties is one that offers much scope for individual judgment, and therefore is a fruitful source of discussion. I propose to lay my views before the Institute as follows:

Deep Level Shafts.—For the development of deep level properties on the Witwatersrand two methods are commonly in vogue, viz:

1. Sinking vertically at a point adjacent to the boundary lying nearest the outcrop, until the vein is intersected; from that point continuing the shaft at an angle off the horizontal, determined by the inclination of the vein.

2. Sinking vertically at a point situated centrally or towards the dip boundary, to such a depth that the lowest point is coincident in level with the intersection between the reef or vein and a vertical line drawn from the outer surface boundary.

Of these methods the first-named is more generally adopted, in fact, may be said to apply to nine out of ten deep level properties.

I propose to consider, therefore, whether for the development of such properties this method is the most commendable.

Firstly, we must define the term "deep level." By this is meant an area of ground which embraces the continuation of certain inclined auriferous rocks, the outcropping portions of which are not included within the superficial area marked by its boundaries; or, in other words, an area of ground, so situated, that, at an estimated depth from surface, the said rocks will, at their intersection with the imaginary vertical line drawn from that superficial limit which lies nearest the outcrop, pass into the said area of ground, and traverse it until by another intersection with a line marking the vertical projection of the outer surface boundary, it passes out of the property.

In the pursuit of gold mining, given that the deposit presents the charcteristics of average grade and width, which are so strongly a feature of the main reef banket series—one of the most important considerations regarding it is, "In what manner can the locked-up metal be earliest made a market commodity?" Of course such a question applies equally to any gold deposit, but the risks attending the exploitation of ordinary quartz reefs, on account of their varying tenor, preclude the possibility of applying any fixed average width and grade to the ore body, and therefore the exploitation can only be carried upon the known shoots, in a manner adapted to their particular features. In such circumstances it is impossible to forecast the amount of development which a mine requires, and hence the development is generally only one step ahead of the stoping faces.

On the Main Reef series, however, on account of the regularity of the deposits, it is customary to deal with areas, as is the case with coal seams, that is, to measure up the superficial boundaries and use their product multiplied into an estimated stoping thickness of reef, to express the tonnage contained, less a certain percentage allowed for error. Attached to the resulting tonnage is a factor of value estimated from the returns of neighboring working mines.

The difference, therefore, between a quartz and a banket mining proposition, is, that whereas in the first instance, development can only be applied locally, and upon restricted lines, it may be planned in the second case to cover the property as a whole.

In viewing the question of the development of banket areas,

therefore, the fact must be borne in mind that the design is to so lay out the initial development work that the succeeding stages will in the least possible time, at the lowest cost, open out the reserves of ore ready for stoping attack. And here we must not imagine that a system by means of which it is possible to reach the gold-bearing material in the shortest space of time, is necessarily the one to be adopted, because, as we have already stated, the ulterior design is the development of the entire property by the quickest and cheapest means which can be employed.

We are met here by a possible objection from the engineer in whose mind the most important issue is the arrival of the producing stage. The importance of this issue will be acceded to by all, but there still remains the question of the best time in the history of a deep level company at which it should be commenced, that is, as to whether it should be reached at all hazards, and without regard to future contingencies, or whether it should take its place in a well regulated method, which has in view the life limit of the property.

Probably the best way to approach this subject is to make a theoretical comparison of the time and cost involved in: 1. Sinking a vertical shaft adjacent to the boundary lying nearest the outcrop to the point of reef intersection, from thence, continuing it upon the reef at whatever angle it assumes, to the other boundary. 2. Sinking a vertical shaft, at a point situated centrally between the inner and outer boundaries, to such a depth that the lowest point is coincident in level with the intersection between the reef and a vertical line drawn from the outer surface boundary. 3. Sinking a vertical shaft at the outer boundary to the point of reef intersection.

To illustrate our arguments and comparisons, we shall take a block 5,000 English feet on strike (east and west) by 3,000 feet in dip direction (north and south) and shall assume that two shafts are required for its development.

Methods of Development.—The methods of attacking the reef itself for the purpose of blocking out ore are identical in all three cases we have named, but they differ from each other in the way the points of attack are reached. In the case of the vertical shaft turned on the reef's dip, these are determined during the sinking and have strict relation to the angle of dip inclination. That is to say, the distance as from level to level, must in every case be a

quantity which depends upon the angle of dip which the reef assumes.

To illustrate this let us take two instances, viz :

1. A reef dipping south at 25 degrees from the horizontal.
2. " " " 60 " " "

Now the ultimate object of levels is to open up ore bodies in such a way that they may be attacked in the quickest and most economical manner, or in a way that provides, firstly, the best practice in ore removal by blasting or otherwise, and, secondly, the least possible handling of the dislodged rocks between the time of dislodgment and delivery at the hauling shaft.

The question of handling is the important consideration in the cases we have under immediate notice.

In the instance we have first cited, that of a reef dipping at 25 degrees, it is patent that the whole of the dislodged ore must be handled from either the level immediately above or that immediately below in any particular stope. If, therefore, these levels are separated by a distance of say 250 feet the broken ore must be shovelled, or in some such manner passed, from the stopes to the level. The time and cost involved in such an operation it is needless to dwell upon, as they are obvious. It is essential, therefore, that the levels be kept within a limit of say 150 to 160 feet to insure ore supply at a reasonable cost.

In the second instance cited, that of a reef dipping at 60 degrees, the angle is sufficiently high to allow the force of gravity to exercise itself upon the ore in such a manner that immediately upon its detachment from the stoping faces it rolls to a point prepared for its reception at the bottom of the stope, from whence it discharges itself through shoots to the trucks below. Here, therefore, no handling is necessary and the distance as between level and level, may vary between the limits of 250 to 300 feet at the discretion of the miner, or in other terms, the levels only require to be placed at such distances, the one from the other, that a sufficient number of faces of attack are available to give ample ore supply to the mill.

Take the first case, in which the reef dips at 25 degrees. Suppose the shaft be sunk at the outer or southern boundary of the property. At a depth of 1,065 feet from surface the first crosscut is started northwards towards the reef, dipping south, which it eventually strikes at 300 feet on incline, from the north boundary

or at the point previously determined upon for the commencement of the second level. The object of first striking the reef at the proposed second level is to obviate the expense of a crosscut from the shaft to each level. A distance of 150 feet on incline at an angle of 25 degrees from the horizontal is only equivalent to about 63½ feet vertically ; therefore if crosscuts were made to each level

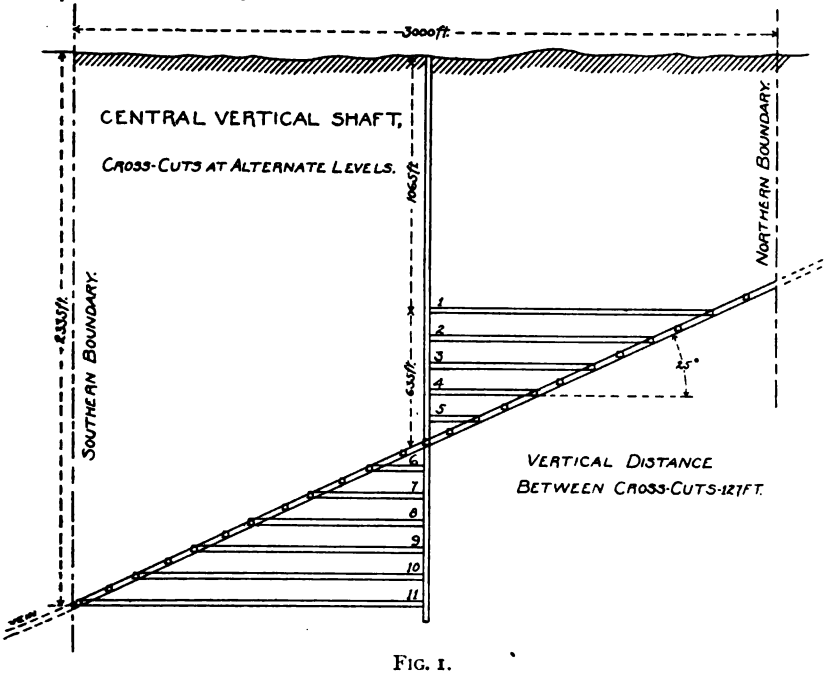

FIG. 1.

on the reef they would only be 63½ feet apart in the shaft. To save the expense of a long crosscut I would propose that the first level be opened from the second. That is, immediately the reef is struck by the main crosscut let raises be commenced, the one vertically until a point is reached horizontal with the point of the proposed first level on the reef, the other, on the reef, to the previously arranged location of the said level, these two points to be connected by a short crosscut.

The stoped ore from above the first level would be transported through the level and crosscut, and dumped through the vertical raise—now winze—to the second level, going from thence through the main crosscut to the shaft. In the same manner 3, 5, 7, 9, 13, 15, 17, 19 and 21st levels would be opened from the 2, 3, 4, 5, 7,

8, 9, 10 and 11th crosscuts respectively. Thus, in developing the reef from the southern vertical shaft, the first crosscut would be started at 1,065 feet and others at intervals of twice 63½ feet or 127 feet, till the bottom of the shaft was reached. In this instance, for the reasons above given, the

1st	and	2d	crosscuts would open the	1st and 2d	levels.
2d	"	"		3d and 4th	"
3d	"	"		5th and 6th	"
4th	"	"		7th and 8th	"
5th	"	"		9th and 10th	"
6th	"	"		11th and 12th	"
7th	"	"		13th and 14th	"
8th	"	"		15th and 16th	"
9th	"	"		17th and 18th	"
10th	"	"		19th and 20th	"

Finally from the shaft would be opened the 21st and 22d "

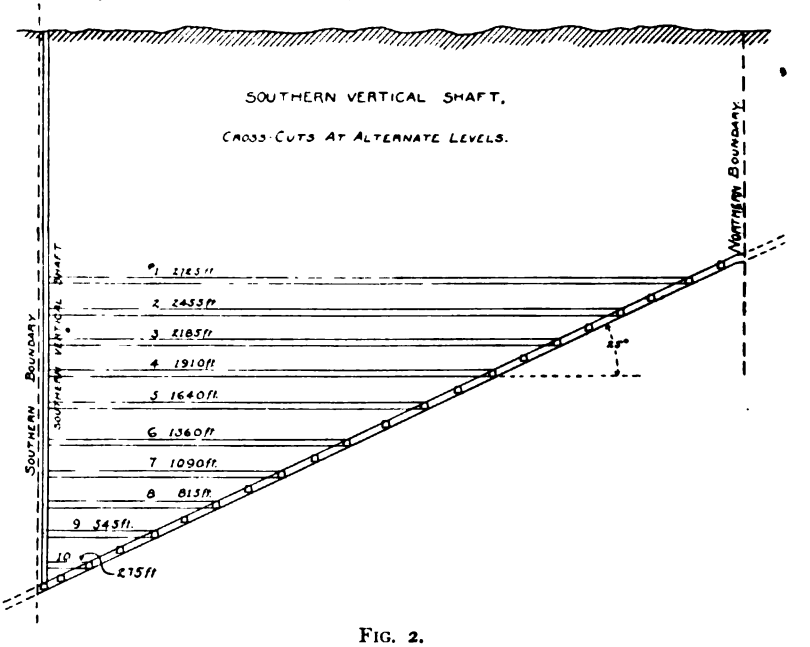

FIG. 2.

Rate of Sinking.—To arrive at a basis for calculation the time and cost of sinking 4-way vertical shafts, I have computed the following schedule, and have allowed the rate of sinking, whether on vertical or incline, to be the same.

The following are the estimated maximum sinking rates:

First 500 feet at rate of 125 feet per month occupies 120 days, and so on as per following table:

	Rate.	Days Taken.	Total Days from Commencement.
1st 500 feet	125	120	120
2d "	120	125	245
3d "	115	130	375
4th "	110	136	511
5th "	105	142	653
6th "	100	150	803
7th "	95	158	961
8th "	90	167	1128
9th "	85	177	1305

It will be observed that I have made a regular progressive decrease in the monthly rate of sinking. This I have designed to cover:

1. Gradually increasing time for haulage.

2. Difficulties of ventilating shafts at great depths. Therefore, (*a*) Temperature is high and men cannot perform a maximum amount of work. (*b*) After blasting, the gases caused by the partial and entire detonation of the explosive material employed, vitiate the atmosphere to such an extent that it is dangerous for workmen to enter; hence, a certain time is lost after each blasting.

3. Gradually increasing time required for haulage, hence (*a*): Proportionately increasing time taken to clear away broken rock after blasting. (*b*) Less time for drilling between the blasting intervals. (*c*) Longer time required for raising and lowering of workmen.

NUMBER OF DAYS OCCUPIED IN SINKING TURNED VERTICAL SHAFT.*—Calculated from the foregoing schedule the number of days occupied in sinking the turned vertical shaft would be as follows:

To Reef.	Feet.	Days.
1st Level (assumed)	1,000	245
2d "	1,150	284
3d "	1,300	323
4th "	1,450	362
5th "	1,600	402.2
6th "	1,750	443
7th "	1,900	483.8
8th "	2,050	525.2

* The term "turned vertical shaft," as used by the author, means a shaft sunk vertically to its intersection with the reef, from a point on the surface adjacent to the property line lying nearest the outcrop; then, from the intersection the shaft follows the dip of the reef. [Ed. QUARTERLY.]

9th	"	2,200	567.8
10th	"	2,350	610.4
11th	"	2,500	653
12th	"	2,650	698
13th	"	2,800	743
14th	"	2,950	788
15th	"	3,100	834.6
16th	"	3,250	882.1
17th	"	3,400	929.4
18th	"	3,550	977.7
19th	"	3,700	1,011.1
20th	"	3,850	1,061.2
21st	"	4,000	1,328
22d	"	4,150	1,181.1

Total Depth, 4,150 feet.
Total Days Sinking, 1,181.

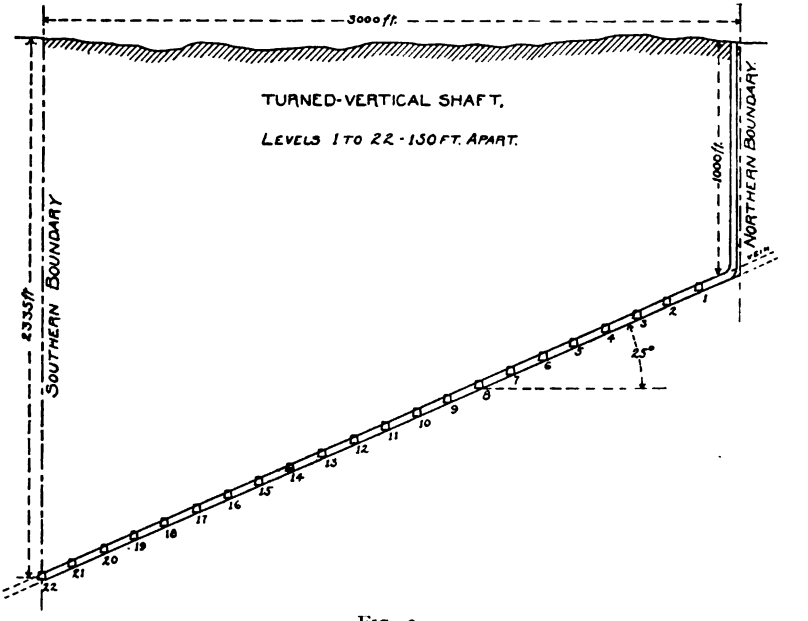

FIG. 3.

TIME OCCUPIED IN SINKING CENTRAL VERTICAL SHAFT.

	Feet.	Days.
Sinking to depth of 1st crosscut.	1,065	262
From 1st to 2d crosscut.	127	33
" 2d to 3d "	127	33
" 3d to 4th "	127	34
" 4th to 5th "	127	34
" 5th to 6th "	127	34
" 6th to 7th "	127	35

From	7th to 8th	crosscut.	127	35
"	8th to 9th	"	127	36
"	9th to 10th	"	127	36
"	10th to 11th	"	127	36
	Total depth,		2,335 feet.	
	Total days,		608	

TIME OCCUPIED IN SINKING SOUTHERN VERTICAL SHAFT.

To depth of	1st crosscut	1,065	262
"	2d "	1,192	295
"	3d "	1,319	328
"	4th "	1,446	362
"	5th "	1,573	396
"	6th "	1,700	430
"	7th "	1,827	465
"	8th "	1,954	498
"	9th "	2,081	534
"	10th "	2,203	570
"	11th "	2,335	608
	Total depth,	2,335 feet.	
	Total days,	608	

I have dealt thus far with the time occupied in reaching the lowest level in each system postulated, and have now to pass on to the time absorbed in driving, crosscutting and rising; assuming these operations to be performed at an all round average of 35 feet per week of 7 days, or say 5 feet per day.

I have already referred to the manner in which I propose to lay out the crosscutting and will now show a schedule calculated from the above postulated rate of progression, which gives the time occupied in reaching the point of each level, under the system of the central and southern vertical shafts.

CENTRAL VERTICAL SHAFT.

No. Crosscut.	Length Crosscut.	Days to Perform.
1	1,225 North.	245
2	955 "	191
3	685 "	131
4	410 "	82
5	140 "	28
6	140 South.	28
7	410 "	82
8	685 "	131
8	955 "	191
10	1,225 "	245
11	1,500 "	300

SOUTHERN VERTICAL SHAFT.

1	2,725	North.	545
2	2,455	"	491
3	2,185	"	431
4	1,910	"	382
5	1,640	"	328
6	1,360		272
7	1,090	"	218
8	815	"	163
9	545	"	109
10	275	"	55

CENTRAL VERTICAL SHAFT—TOTAL DAYS TO REACH REEF.

A. Number of crosscut.
B. Days sinking in shaft.
C. Days to crosscut to reef.
D. Total days from commencement of shaft to strike reef.

A.	B.	C.	D.
1	262	245	507
2	295	191	486
3	328	131	459
4	362	82	444
5	396	28	424
6	430	28	458
7	465	82	547
8	498	131	629
9	534	191	725
10	570	245	815
11	606	300	906

SOUTHERN VERTICAL SHAFT.

A.	B.	C.	D.
1	262	545	807
2	295	491	786
3	328	431	759
4	362	382	744
5	396	328	724
6	430	272	702
7	465	218	683
8	498	163	661
9	534	109	643
10	570	55	625

The schedules above tabulated show the number of days calculated from the time the shaft work started, to cut the reef from the central and southern vertical shafts, respectively. These points mark, firstly, the place from which eleven levels would be driven

on the reef, and secondly, the starting point for the rises to form the immediate levels, in the manner before explained.

We have now to consider the additional time necessary to reach the starting points of the said intermediate levels. The distance to rise on the reef is in each case 150 feet, which would occupy at the rate of progression assumed 30 days. The totals are therefore as follows :

A. Number of crosscut.

B. Total days from commencement of shaft to strike reef in central vertical shaft, and

C. In southern vertical shaft.

D. Days occupied in rising.

E. Total days to reach points of intermediate levels in central vertical shaft, and

F. In southern vertical shaft.

A.	B.	C.	D.	E.	F.
1	507	807	30	537	837
2	486	786	30	516	816
3	459	759	30	489	789
4	444	744	30	474	774
5	424	724	30	454	754
6	458	702	30	488	732
7	547	685	30	577	713
8	629	661	30	659	691
10	815	625	30	845	655
11	906	—	30	936	—

We are now brought to the question of the order in which the levels would be struck in each of the three systems we now have under consideration. These are shown in order in the following table :

A. Number of level.
B. Turned vertical.
C. Number of level.
D. Central vertical.
E. Number of level.
F. Southern vertical.

A.	B.	C.	D.	E.	F.
1	245	10	424	22	606
2	284	8	444	21	615
3	325	9	454	20	625
4	362	12	458	18	643

A.	B.	C.	D.	E.	F.
5	402	6	459	19	655
6	443	7	474	16	661
7	483	4	486	17	673
8	525	11	488	14	683
9	567	5	489	15	691
10	610	2	507	12	702
11	653	3	516	13	713
12	698	1	537	10	724
13	743	14	547	11	732
14	788	13	577	8	744
15	835	16	629	9	754
16	882	15	659	6	759
17	929	18	725	7	774
18	978	17	755	4	786
19	1,011	20	815	5	789
20	1,061	19	845	2	807
21	1,128	22	906	3	816
22	1,181	21	936	1	837

Analyzing these results we obtain the following comparisons—Number of levels ready for driving within 600 days under each system: Turned Vertical, 9; Central Vertical, 14; South Vertical, nil.

So far we have dealt only with the time occupied in preparing for the level attack. We now go a step further and deal with the time occupied in the development of each level and the comparative time taken in the development of the whole of the ore.

The size of the property we have stated to be 5,000 x 3,000 English feet. In this length two shafts would be required where the distance between the shafts is 1,200 feet, and that from the shafts respectively to each outer boundary of the property east and west 1,800 feet.

The levels will therefore be of the following lengths:

1. From the turned vertical, 4,960 feet.*
2. From the central and southern vertical, 5,000 feet.

Having two shafts there would be four faces of attack presented, therefore, at the rate of driving postulated, five feet per day, the time taken to drive a level in each case would be as under:

Turned vertical, ... 248 days.
Central vertical, ... 250 days.
Southern vertical, ... 250 days.

* The 40 feet deducted from the total length of 5,000 feet is to allow for the space occupied by the two inclined shafts. [Ed. QUARTERLY.]

The total time required to drive each level from the date of commencement of shaft sinking would therefore be as shown in the following schedule:

TIME OCCUPIED IN DEVELOPMENT.

Turned Vertical.		Central Vertical.		Southern Vertical.	
No. of Level.	Days.	No. of Level.	Days.	No. of Level.	Days.
1	493	10	674	22	856
2	532	8	694	21	865
3	571	9	704	20	875
4	610	12	708	18	893
5	650	6	709	19	905
6	691	7	724	16	911
7	731	4	736	17	923
8	773	11	738	14	933
9	815	5	739	15	941
10	858	2	757	12	952
11	901	3	766	13	963
12	946	1	787	10	974
13	991	14	797	11	982
14	1,036	13	827	8	994
15	1,083	16	879	9	1,004
16	1,130	15	909	6	1,009
17	1,177	18	975	7	1,024
18	1,226	17	1,005	4	1,036
19	1,259	20	1,065	5	1,039
20	1,309	19	1,095	2	1,059
21	1,376	22	1,156	3	1,066
22	1,429	21	1,186	1	1,087

From these figures we may show the levels opened within a given period under each system; the heading of the columns denote days, the figures in the columns denote the level numbers.

TURNED VERTICAL.

	800	900	1,000	1,100	1,200	1,300	1,400	1,500
1								
2		9	11	14	16	18	20	22
3								
4		10	12	15	17	19	21	
5								
6			13					
7								
8								
Totals,	8	2	3	2	2	2	2	1

CENTRAL VERTICAL.

	800	900	1,000	1,100	1,200	1,300
	10					
	8	13	15	17	22	0
	9					
	16	18	20	21		
	12					
	6		19			
	7					
	4					
	11					
	5					
	2					
	3					
	1					
	14					
Totals,	14	2	3	2	1	

SOUTHERN VERTICAL.

	800	900	1,000	1,100	1,200
	0	22	19	9	
		21	16	6	
			17		
			14		
		20	15	7	
			12		
		18	13	4	
			10	5	
			11	2	
			8	3	
				1	
Totals	0	4	10	8	

The next step is to reduce the development to its terms of ore tonnage.

The dimension of the property we have already stated to be 5,000 x 3,000 English feet. Dip of the reef 25 degrees from the horizontal. Then the increased dip dimensions, due to inclination, equals 198 feet.

Estimated stoping thickness of ore as follows:

Main reef,	4 feet.
Main reef leaders,	3 "
South reef,	3 "
Totals,	10 "

For the purpose of this paper I have only assumed one drive at each level.

Then, 5,000 × 3,000 × 10 = 150,000,000 cubic feet.
Deduct 10 per cent. = 15,000,000 "
135,000,000 "
Assume 12 cubic feet per ton = 11,250,000 tons.
Available ore tonnage, say, 11,000,000.
Each of the 22 levels would therefore develop

$$\frac{11{,}000{,}000}{12} = 500{,}000 \text{ tons.}$$

Hence, summarizing the "time occupied in development statement" on a basis of 500,000 tons per level the following table shows the tonnage development achieved in a given period under each system.

TURNED VERTICAL.

800	900	1,000	1,100	1,200
4,000,000	5,000,000	6,500,000	7,500,000	8,500,000
	1,300	1,400	1,500	
	9,500,000	10,500,000	11,000,000	

CENTRAL VERTICAL.

800	900	1,000	1,100	1,200
6,500,000	7,500,000	8,500,000	10,000,000	11,000,000

SOUTHERN VERTICAL.

800	900	1,000	1,100
Nil.	2,000,000	7,000,000	11,000,000

Therefore, 800 days after commencement of operations the development stands thus:

Turned Vertical . . . . . 4,000,000 tons.
Central Vertical . . . . . 6,500,000 tons.
Southern Vertical . . . . . Nil.

The total tonnage is therefore developed as follows:

Turned Vertical . . . . . 1,500 days.
Central Vertical . . . . . 1,200 days.
Southern Vertical . . . . . 1,100 days.

We are now led to the important consideration of the costs involved in the development under each system.

We shall assume that in each case the averages are as follows:
From surface to 2,000 feet at £35 per foot.
From 2,000 to 4,500 feet at £40 per foot.
Crosscutting and rising at £5 per foot.
Driving levels, say all round average of £5 per foot. Then the costs are as follows:

TURNED VERTICAL.

Sinking 4,000 feet at £35,	£140,000	
" 4,300 feet at £40,	172,000	
		£312,000
Driving 109,120 feet at £5,		445,600
Grand Total		£857,600

CENTRAL VERTICAL.

Sinking 4,000 feet at £35,	£140,000	
" 670 " " 40,	26,800	
		£166,800
Crosscutting and rising 18,685 feet at £5,		93,425
Driving 109,120 feet at £5,		545,600
Grand Total,		£805,725

SOUTHERN VERTICAL.

Sinking 4.000 feet at £35,	£140,000	
" 670 " 40,	26,800	
		166,800
Crosscutting and rising 26,905 feet at £5,		134,525
Driving 110,000 feet at £5,		550,000
Grand Total,		£851,325

Summarizing these results we have the following comparison: Cost to develop the property by

1. Turned Vertical Shaft, ... £857,600
2. Central " " 805,725
3. Southern " " 851,325

Difference in cost 1st and 2d method in favor 2d, fifty-one thousand, eight hundred and seventy-five pounds sterling, ... £51,875

Difference in cost 1st and 3rd method in favor 3d, six thousand, two hundred and seventy-five pounds sterling £6,275

Difference in cost 2d and 3d method in favor 2d, forty-one thousand, one hundred pounds sterling, ... £41,100

From the above summary we see that the central vertical shaft will develop the property at much less cost than either the turned or southern vertical system. In my further remarks I shall leave the southern vertical out of consideration, as it has been clearly demonstrated to be inferior to the central vertical.

The advantage claimed for the turned vertical is that its location ensures the earlier striking of the reef, and consequently, returns may sooner be made than with the central vertical. I have shown, that whereas the first level would be opened in the turned vertical is 493 days from the time of commencement of shaft, from the central vertical it would take a period of 674 days, or 181 days longer.

The question then arises, What practical advantage accrues to a company which, by the adoption of the turned vertical, may start milling six months earlier than one which adopts the central vertical method? The obvious reply is, that the one company can have distributed half a year's profits before the other company begins. But does this necessarily imply a permanent advantage? Let us examine the matter under the following heads:—

1. The equipment required in: (*a*) The turned vertical shaft. (*c*) The central vertical shaft.

2. The comparative running costs of the respective plants.

Equipment for Two Vertical Shafts.

The depth of the shafts under immediate consideration is 4,150 feet, made up of 1,000 feet vertical and 3,150 feet at an angle of 25 degrees from the horizontal.

We shall assume that a three-ton skip, and one-and-a-quarter-inch-diameter crucible steel rope are used, in a two-hoist-way shaft

To cumpute the required H.P. on a hoisting plant we must calculate the powers for both a vertical and incline shaft.

The following formula expresses, with ample allowances, the required H.P. for an engine hoisting a load out of a two-hoist-way vertical shaft, at a given rate of speed. H.P. = net weight of load, plus weight of one rope, times speed in feet per minute divided by 33,000; add 25 per cent. for contingencies, friction, etc.

To find the H.P. of an engine for hoisting a given load up a double track incline in a given time, the following may be used: H.P. = (length of incline in feet times natural sine of angle of inclination), divided by given time in minutes times net weight of

load, plus weight of one rope, divided by 33,000 and add one-third for friction, etc.

Then in the case of the turned vertical shaft under notice the following computation shows the required H.P.

Length of incline in feet, ...	3,150
Nat. sine of angle of 25 degrees, .	.4226183
Time hauling, minutes, ...	2
Net weight of load, ...	6,000 lbs.
Weight of rope, ...	10,425 "

Then $\frac{3{,}150 \times 4{,}226{,}183}{2} = 66{,}562$

$6{,}000 + 10{,}425 = 16{,}425$

$665.62 \times 16{,}425 = 10{,}932{,}808.5$

$\frac{10{,}932{,}808.5}{33{,}000} = 331.3$ h. p. $+ \frac{1}{3} = 441.7$

for the incline,

The lift through the vertical shaft is 1,000 feet.

Then by the preceding formula.

Net weight of load	6,000 lbs.
Weight of 1,000 feet of rope	3,000 "
Speed per minute	2,000 feet.

Then $6{,}000 + 3{,}000 = 9{,}000 \times 2{,}000 = \frac{18{,}000{,}000}{33{,}000} = 545.4$ h. p.

Add ¼ for friction .·. 545.4 + 136.3	= 681.7 "
Then required h. p. for inclined portion	= 441.7 "
" " " for vertical "	= 681.7 "
Total " to hoist from lowest level	1123.4

In case of the central vertical under notice the following computation shows the required h. p.

Net weight of load, ...	6,000 lbs.
Weight of one rope, ...	6,000 "
Speed in feet per minute	2,000 "

Then by the preceding formula

$(6{,}000 + 6{,}000) \times 2{,}000 = 24{,}000{,}000.$

$24{,}000{,}000 \div 33{,}000 = 727.3$ to which add 25% = 909.1 h. p.

Total h. p. required for each turned vertical	1123.4
" " " " " central "	909.1

showing a difference of 214.3 h. p. in favor of the central vertical equipment or a total of 428 h. p. in the complete shaft installations.

The steaming plant required would be, allowing a margin in each case:*

For each turned vertical shaft 6 boilers of 200 h. p.
" " " " " 5 " " "

Cost of Running the Plant.

For our purpose, this may be considered only as important from the standpoint of fuel consumed in each case.

Now, a simple non-condensing winding engine, such as is generally in use on the Witwatersrand fields requires about 35 to 40 lbs. of steam per horse power per hour. The evaporative power of a good Transvaal coal is about ten lbs. of water per pound of coal.

Then the coal required is say four lbs. of coal per horse power per hour. In the instance under notice, the coal required for each turned vertical shaft, winding from the lowest level would be $1123.4 \times 4 = 4493.6$ lbs. of coal per hour, equal to 1617.6 tons per month of 30 days, or 3235.2 tons per month consumed on the two engines.

For the central vertical the coal required for each shaft installation would be as follows:

$909.1 \times 4 = 3636.4$ of coal per hour, equal to 1380.3 tons per month of 30 days, or 2760.6 tons consumed on the two engines.

The comparison in coal consumption would therefore be

Turned verticals . . . . . 3235.2 tons per month,
Central verticals . . . . . 2760.6 tons per month,
Balance in favor of central vertical, 474.6 tons per month.

Reducing this tonnage to monetary terms, and calculating coal as averaging 20 s. per ton on the Witwatersrand, we find the monthly saving to amount to, say, £474 10 s.

Time Occupied in Winding.

The speed of winding in deep vertical shafts, with modern plant, should not average less than 2,000 feet per minute, nor in deep incline shafts less than 1,500 feet per minute.

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*Unless it be intended to keep one boiler in reserve, this boiler capacity appears excessive. The total boiler house power need not equal the maximum power required at the beginning of the hoist from the bottom level, because of the storage of steam during the intervals between hoists. [Ed. of QUARTERLY.]

Assuming that the respective operations of stopping and filling, and stopping and dumping, the skin occupy 1½ minutes, the time required to hoist from the turned vertical and central vertical shafts, on this basis, would then be as follows:

Turned vertical, lowest level, continuous hoist from surface.

Filling skip, ... 1.5 minutes.
Hoisting throughout at rate of 1,500 ft. per min., . . 2.7 "
Tipping, ... 1.5 "

The round trip, that is the time occupied in the various operations, from the time of filling the skip till its return, would be 8.4 minutes.

The absolute tonnage that could be hoisted from this shaft, using 3 ton skips and two hoistways, would therefore be 42.8 tons per hour or 1,027.2 per day.

Turned vertical, lowest level, winding in sections.

Filling skip bottom, ... 1½ minutes.
Hoisting on incline, say, ... 2 minutes.
Filling into vertical skip, ... 1½ minutes.
Hoisting to surface, ... ½ minute.
Tipping at headgear, ... 1½ minutes.

The round trip therefore occupied 9½ minutes. The absolute tonnage that could be hoisted from the shaft, using 3-ton skips and two hoistways, would therefore be 38.8 tons per hour or 933.6 tons per day.

CENTRAL VERTICAL SHAFT.

Filling skip, ... 1½ minutes.
Hoisting, say, ... 1.2 minutes.
Tipping, ... 1½ minutes.

Then the round trip would occupy 5.4 minutes.

The absolute tonnage that could be hauled from this shaft, using 3-ton skips and two hoistways, would therefore be 66.6 tons per hour or 1,598.4 tons per day.

Doubtless there are some engineers who will charge me with providing too much power for winding engines. It is my practice to specify a pair of engines, either of which is equal to the hoisting of the load. For fast winding it must not be forgotten that the time the power is required is in the first few seconds of wind, so that speed may be attained within the shortest space of time, and

in order to have the required power at command at that stage it is necessary to provide ample engine power.

It is palpable from these deductions that there is only a seeming advantage in the earlier distribution of profits, under the conditions named, and that the more permanent benefit is derived by awaiting the results obtainable from the adoption of the central shaft method.

Summary.

Summing up our conclusions upon this theoretical basis we find that the vertical shaft as a system is preferable to the turned incline system in the exploitation of deep level properties, and that of vertical systems, the central vertical fulfills the requirements of an economic and time saving method to the highest attainable standard.

Hence the general practice of the Witwatersrand, which is almost exclusively the employment of the turned vertical system, is not destined to prove the best method. We have seen that it can only claim one advantage over the vertical shafts, and this, in the light of the entire life of the property, I have shown to be quite questionable. On the other hand, it possesses the following very serious disadvantages:

1. The shaft needs heavier equipment.
2. The distance to haul is longer.
3. The cost of haulage is considerably greater.
4. Less ore can be hauled in a given time.
5. The time to develop the property is greatly increased.
6. The cost to develop the property is greatly increased.
7. The maintenance of the shafts is greater.
8. The pumping plant must be heavier.
9. Less facilities for the transport of workmen.

Ore Sorting.

The principle of ore sorting is one that is gradually obtaining a firm footing amongst modern mining methods and therefore its claims to consideration may fittingly be discussed here. It must first be stated that there is a very wide difference of opinion amongst mine managers as to the advantage or otherwise of adopting this method in the milling of their ores. Many of them are firm in the conviction that a better result is obtained when taking ore in the

face and sending the whole to the mill than in having recourse to sorting. Others are equally satisfied that the adoption of the principal means an increment of additional revenue in the ore treatment. The fact that the question of sorting is a debatable point suggests:

1. An intermixed product is to be handled.

2. The possibility of so reducing the intermixture in the first case as to leave no profitable sorting margin.

3. That sorting is only profitable within prescribed limits.

In their practical application these deductions mean:

1. That the miner in breaking his ore has included in the blasting a proportion of poorer extraneous rock, which, by intermixture with the higher grade ore, has reduced the milling grade.

2. That the blasting operations should, if possible, be done in such clean material, that only an inappreciable quantity of the poorer rock is included.

3. That, if a given width of reef contains practically all the gold, and that width only is extracted, the operation of sorting is necessarily superfluous.

Examining these practical deductions, we find that they involve in their enunciation certain premises which it is our duty to examine. We observe firstly that they premise the possibility of the miner's work delivering a clean product. Such a premise is only admissible, if the ore is of sufficient width to make workable stoping room for those engaged in the work of its extraction. The workable width of stope is a quantity entirely dependent on the angle of dip which the reef assumes. If it be vertical, or near to that, it would be possible to carry a 2-foot stope if the reef parted clearly from its enclosing walls. In banket, it is not usual to find the reef absolutely separated from the walls, particularly on the hanging-wall side, where almost invariably there occurs attached to the wall a thin line of pebbles, generally rich in gold. As the angle of inclination becomes lower, or, in other words, as it approaches the horizontal, so, *pari passu*, does the difficulty of carrying a narrow stope increase until at flat angles of from 12 degrees downwards, the workable width cannot well be less than 3 feet to 3 feet 6 inches. Assume that in the latter instance the valuable portion of the ore is only from 6 to 12 inches (in which case the ore must be unusually rich) in width, there is obviously a large admixture of poor or barren rock to deal with, and the question of "What

advantage can be derived by sorting out the poorer gangue?" is now pertinent. If, on the other hand, the reef under operation is from 10 to 30 feet in thickness, with zone or payable rock averaging 4 to 5 feet in width within the body, the payable ore can be extracted without serious intermixture, irrespective of the reef's dip, etc.; therefore, in such a case, sorting has no application. If, however, an average stoping thickness of say 3 feet be taken in any mine, it will be found that there are frequently intercalated layers of barren sandstone, or quartzite, within the ore body, which materially reduce the average grade. And here is the crux of the question of the advantage, or otherwise, of sorting.

I have previously stated that many mine managers are firm in the conviction that a better result is obtained in taking ore in the face and sending all to the mill, than in having recourse to sorting. Even in the last case I have mentioned, namely, that of a reef containing layers of sandstone, if the diluent rock contains 3 or 4 dwts. of gold per ton, and a large quantity is being treated, the advantage of sorting remains a very open question, but if, on the other hand, the diluent rock is valueless, a different element is introduced, because in reduction of ore in a battery, the mixture of valuable ore with valueless gangue enriches the latter at the expense of the former. In other words, a quartzite worth nothing before going into a battery will, when pulverized with valuable rock during the stamping process, be converted into tailings worth possibly up to 4 or 5 dwts. per ton.

I propose to show, in as concise a manner as possible, in what directions sorting is advantageous.

Let us assume, on the one hand, that the rock under treatment has a recoverable value of 10 dwts. in the mill and on the other that the ore is subjected to sorting, and that 35 per cent. of the rock is rejected. Then we have—on a basis of 100 tons—100 tons of ore as delivered from the mine containing 1,000 dwts. of recoverable gold.

Let 35 per cent. of this be sorted out.

Assume the rejected ore to contain 1 dwt. per ton; then 35 tons contain 35 dwts.

The 65 tons of assorted ore contain 965 dwts. equal to 14.85 dwts. per ton. The sorting has therefore produced 65 tons of 14.85 dwts. ore. We shall assume that the total gold is recovered from each parcel of ore, then—

100 tons containing 1,000 dwts. at say 3 6 per dwt. = £175 0 0
65 " 965 dwts. " " " = 168 17 6

The cost in each count we may place as follows:

Mining, including pumping and raising,	£ 0	10	0	per ton.
Development and redemption,	0	3	6	"
Transport,	0	0	9	"
Milling,	0	2	6	"
Cyaniding,	0	5	0	"

UNSORTED ORE.

Mining 100 tons at 10s,	£50	0	0	"
Development and redemption at 3s 6d,	17	10	0	"
Transport at 9d,	3	15	0	"
Milling at 2s 6d,	12	10	0	"
Cyaniding,* 70 tons, at 5s,	17	10	0	"
Total cost,	£101	5	0	

COST OF SORTED ORE.

Mining, 65 tons, costs,	£ 50	0	0	"
Development and redemption,	17	10	0	"
Transport, 65 tons, at 9d,	2	8	9	"
Milling, 65 tons at 2s 6d,	8	2	6	"
Cyaniding, 45 tons at 5s,	11	5	0	"
Sorting, 35 tons at 1s 6d,	2	12	6	"
Total cost,	£91	18	9	
Cost per ton, 28s 6d.				

The increase of grade as shown above is from 10 dwts. to 14.85 dwts. per ton.

In production of any kind given that the demand cannot be exceeded—which is true of the gold industry—the important factors are:

1. What is the limit of individual production?
2. How best may that limit be reached?

In the case of a company running 100 stamps, we may place the limit of capacity at, say, 13,000 tons of ore per month. Assume that the ore is unsorted, aud that its treated value is 10 dwts. of gold, worth 3s 6d per dwt. and we have 13,000 tons treated returning 6,500 ozs. of gold at £3 10s per oz. £22,750. Under the conditions named, therefore, the limit is reached.

Assume again, that a company working under exactly similar conditions as the last, on the same grade of rock, erected 65

* The remaining 30 tons pass away in form of slimes.

stamps, and introduced a system of sorting which enabled it to reject 35 per cent. of the rock mined. Now, the limit of this company's production, as compared with the last, is equal to 65-100ths of 13,000 tons, that is, 8,450 tons, whose value treated is not, however, 10 dwt. in the mill, as in the unsorted ore, but the grade the sorting has produced 14.85 dwts. per ton. The product from this ore is 8,450 tons, yielding 14.85 dwts. per ton, equal to 6274.1 ozs. at £3 10s per oz., equal to £21,959 9s, or practically what was obtained by the first company. Here, however, the difference is, that only 65 stamps are required in place of 100 in the first instance cited, and hence the adoption of sorting has saved the capital outlay represented by the difference betwen 65 and 100 stamps equipment, plus the constant charges for interest, maintenance, depreciation, etc.

But here a new aspect is opened, namely the limit of time in which a certain product may be available for realization. And here, in my opinion, is a factor in ore sorting which is generally lost sight of.

Assume, for example, that the company last cited increases its plant to 100 stamp basis, then the proportion would appear thus:

100 stamps crushing 13,000 tons from which 14.85 dwts. of gold is recoverable, equal 9,652.5 ozs. at 70s per oz., £33,783 15s.

That is to say, in the limit of one month's time, the value of the company's production has risen from £21,959 9s to £33,783 15s. whilst the total running expenses are as follows:—

13,000 tons unsorted ore at 20s 3d per ton	£13,162 10 0
13,000 tons sorted ore at 28s 4d per ton	18,416 13 4

The sorted ore has therefore produced a total of £33,785 15s at a cost of £18,416 13s 4d, whilst the unsorted ore has produced £22,750, at a cost of £13,162 10s.

Figuring these results out on an everyday proposition we have the following, showing, firstly, the results from unsorted ore, and, secondly, the results from that sorted.

UNSORTED ROCK BASIS.

Milling capacity, 100 stamps.
Recoverable gold per ton, 10 dwts.
Cost per ton, 20s 3d.
13,000 tons ore milled worth 35s per ton.

Total monthly production, ...	£22,750 0 0
13,000 tons treated at 20s 3d per ton, ...	13,162 10 0
Monthly profits, ...	9,587 10 0
Annual profit, ...	115,050 0 0

SORTED ROCK BASIS.

Milling capacity, 100 stamps.
Recoverable gold (as previously shown) 14.85 dwts.
Cost per ton, 28s 4d.
13,000 tons of ore milled worth 51,975 shillings.

Total monthly production, ...	£33,784
13,000 tons treated at 28s 4d per ton, ...	18,417
Monthly profit, ...	15,367
Total annual profit, ...	184,404

SUMMARY.

Unsorted ore produces, ...	£115,050	annual profit.
Sorted ore produces, ...	184,404	" "
Balance in favor of sorting, . .	69,354	" "

It must, however, be borne in mind that if a company milling unsorted ore is exhausting the deposit at the rate of 13,000 tons per month, the company which is sorting out 35 per cent. and milling an equal quantity, is exhausting its deposits at the rate of 20,000 tons per month. Or, to reduce the facts to a practical statement, we have the following:

Assume that in each case the companies own an untouched area of 50 claims, which contain an aggregate of 1,500,000 tons of ore. The company milling unsorted ore mines 13,000 tons per month; therefore its life upon the area given is 9.6 years. The company milling sorted rock mines 20,000 tons per month; therefore its life, on the area given, is 6.3 years, or 3.3 years less than in the former instance. The second company, however, only mills 65 per cent. of the ore that it mines, whereas the first company mills the entire quantity.

Therefore:

First company mills 1,530,000 tons at profit of 14s 9d per ton, equal £1,106,250.

Second company mills 975,000 tons at profit of 23.64 shillings per ton, equals £1,152,547.

Balance in favor of sorting £46,297.

It is plain therefore, that although the costs per ton of sorting ore are apparently higher, they are not so in fact. To illustrate this more clearly:

The total cost to produce and treat 975,000 tons of rock is 975,000 x 28s 4d, equals £1,381,250. This sum spread over the whole tonnage in the area we have named:—1,500,000 tons of ore = £1,381,250 ÷ 1,500,000 equals 18s 5d per ton.

The cost of treatment of unsorted ore is . . .	20s 3d	per ton.
Cost of sorted ore spread over same tonnage,	18s 5d	" "
Sorted rock cost less by	1s 10d	" "

As a setoff to this however, we have the following:

1,500,000 tons of ore yielding 10 dwts. equals 15,000,000 dwts.
15,000,000 dwts. at 3s 6d per dwt. equals. . . . £2,625,000
975,000 tons of sorted ore yielding 14.85 dwts. = 14,478,750 dwts.
= £2,533,781

Gold value contained n unsort ore, . . .	£2,625,000
" " " " sorted ore, ...	£2,533,781
The balance therefore is	$91,219
Treatment of unsorted ore 1,500,000 tons at 40s 3d,	£1,518,750
" " sorted ore 975,000 tons at 28s 4d, . .	1,381,250
The saving in expenses on sorted ore is, ...	£137,500

Total loss in gold yield:

1,500,000 tons produce	£2,625,000
975,000 "	2,533.781
	£91,219

Total balance in favor of sorting = £137,500 = £91,219 equals £46,281.

Balance per ton in favor of sorting, 617 shillings.

We have, therefore, shown upon the propositions instanced, that not only is there a direct revenue increase due to sorting of say £47,000, but that the total recovery is made in a period of 3.3 years less than is the case when working unassorted ore. The importance of the lesser term from the financiers' standpoint is so patent, that it needs no illustration.

THE PROGRESS IN ORE DRESSING.*—I.

BY C. BLÖMEKE.

A. The Dressing of Silver, Lead and Zinc Ores.

1. Ordinary dry and wet dressing.

The continuous system of ore dressing was first introduced by the engineer Geier in 1862, in the lead-ore division of the large Silberau† Mill at Ems. Then the blende and mine fines ‡ divisions of the same mill followed, as did also the large Central Mill at Clausthal § (started in 1871 and 1872), the mill at Laurenburg a. d. Lahn ‖ and the mill of the Perm ¶ Mines at Ibbenbüren (Westphalia), at Bleicharley ** at Beüthen, and at Friederichsegen at Oberlahnstein, etc.

These dressing works, formerly known as models of their kind, have been greatly improved upon during the last nine years, in the mills built by the engineer C. Lührig, deceased. Lührig, after perfecting the dressing of coal, made great progress in ore dressing in building the mills at Freiberg, Ramsbeck (Westphalia), Werlau at St. Goar on the Rhine, Laurenburg and other large mills outside of his own country.

These mills can be considered the best and most complete in existence at the present time, as regards system, cheapness of product, and small loss of mineral in dressing. In what follows, these mills will be compared with those previously mentioned as modern, also discussing, however, their disadvantages as well as the advantages they possess over mills erected by others.

The Arrangement of Apparatus.

While formerly in flat districts, and with little favorable topography, the various divisions of a mill were arranged on one plane or on two foundations of but little difference in elevation, as, *i. e.*, at Ems, at Selbeck near Dusseldorf and even in the former mill at Laurenburg situated on the steep terraced banks of the Lahn,

*Translated by Charles Fulton from the "Berg und Hüttenmannisches Jahrbuch."

†No. 44, d. B. u. H. Z., 1864.

‡No. 30, 35 u. 36, d. B. u. H. Z, 1882.

§Zeitschr. f. d. B. H. u. S. W., 21 Bd., 1873, u. No. 4, 5 u. 6, d. B. u. H. Z., 1882.

‖No 15 d. B. u. H. Z., 1882.

¶No. 45 u. 46 d. B. u. H. Z., 1874.

**Zeitschr. f. d. B. H. u. S. W., 3 Heft, 1885, u. No. 48, d. B. u. H. Z., 1885.

Lührig in similar districts has applied his system of lofts or floors, first used by him in his coal breakers, but never before used in ore dressing mills.

This floor system consists in placing directly above each other the various divisions for the dressing of the ore, down to 4 mm. size. All these divisions are placed in one building of four floors. For the treatment of the mineral of less than 4 mm. size, a second building is erected behind the main building, with a foundation 4 m. lower.

In these mills, the hand dressing is done at the shaft level, and then the dressing mineral is lifted by elevator from the shaft level to the top floor of the main building.

Plate I., Figs. 7 and 8 represent such a mill, being a plan of the large Central mill of the Himmelfahrt mine at Freiberg. (Compare Jahrb. f. d. B. u. H. W. Koenigreiche Sachsen, 1890, and No. 25, d. B. u. H. Z., 1891). The mill is a combination of the terrace and floor system, the latter being the more prominent feature. This mill is more modern than that at Ems (the Silberau) in building and design, as well as regards the separate dressing of the various classes of ores.

The Silberau mill has a division for the mine fines (Pl. I., Figs. 1 and 2), one for lead ores (principally galena), and a third for blende ores, these departments however, being in three different and separate buildings.

The Himmelfahrt mill consists of two divisions containing similar machinery, one for the precious ores and the other for the silicious lead ores.

For the dressing of lead and zinc ores from large mines, Lührig has adopted the same method, in that he uses one division to dress lead ores and the other to dress zinc ores.

Regarding principle, this is nothing new, as the mill at Ems acted as pioneer in this method. Also the housing of the machinery and appliances for the dressing of the two classes of ores in one building as at Freiberg, Ramsbeck and Laurenburg is not new, as the author advocated this plan in his design for a galena and blende dressing mill. (Compare No. 43 der B. u. H. Z., 1875.)

However the method of Lührig is to be preferred.

Recurring to the comparison of the Himmelfahrt and Silberau mills, the following points are noted: The first has an interior area of but 1,000 square meters (about) to that of 3,550 square

meters of the Silberau mill. The four floors of the main building at Freiberg have a total area of 1,585 square meters to which must be added that of the sand and slime floors, making a total of 2,230 square meters against 3,550 square meters at the Silberau mill.

At Freiberg, the space filled with machinery is 10,350 cubic meters against 15,000 cubic meters at the Silberau.

The Silberau mill contains the following machinery.

A. MAIN BUILDING.

Fourth floor.—4 rock crushers, 4 grizzleys.

Third floor.—2 screens (trommels), 2 picking belts, 2 coarse rolls.

Second floor.—2 trommels, 2 medium rolls, 12 jigs.

First floor.—(Foundation), 2 trommels, 2 fine rolls, 6 jigs, 30 stamps 4 bucket elevators.

B. SIDE BUILDING.

4 trommels, 2 sand classifiers, 12 sand jigs, 4 slime spitzkasten apparatus, 14 Stein tables, 9 Bilharzi, 2 bucket elevators, and 4 pumps.

This machinery requires, counting loss in transmission, about 93 H. P. which are developed by a compound engine, placed in a separate building on the level with the main building.

Three tubular boilers, Steinmüller type, each of 110 s. m. heating surface generate steam at a pressure of 7½ atmospheres. The power for the elevator is developed by a separate engine of 8 H. P.

The mill has easily a capacity of 150 tons of ore per ten hours and can treat 200 tons. It employs the following force: 45 laborers, 3 foremen, 1 engineer, 1 fireman and 5 mechanics; all told, 55 men. These figures were demonstrated on the contractors turning over the mill. At that time the repairs were small in amount and a larger force of mechanics not necessary. The cost of dressing was then 8 pf. per 100 kg. of ore, exclusive of rough sorting and hand picking.

According to Köhler, p. 165, Zeitschr. der Ver. Deutcher Eng., 1893, the cost of dressing at the old mill at Himmelfahrt was:

For sorting separating, cobbing, ...	2.00	mk.	per	ton.
" cleaning, followed by cobbing and jigging,	1.40	"	"	"
" crushing with rolls and jigging, ...	0.48	"	"	"
" stamping and concent. on tables, ...	1.76	"	"	"
" transportation and experiments, ...	4.00	"	"	"
Total	9.64	"	"	"

or 96 pf. per 100 kg., which is very much more than with the new system of dressing.

The capacity and economical cost of dressing at the latter works on their delivery compared so favorably with the Silberau mill, because only silver and galena products were made, and these not greatly enriched; with blende products made at the same time the result would be different.

Within the last two years the ore is classified at Himmelfahrt before dressing as follows:

Into pyritiferous, arsenical, copper-bearing and zincy ores, in order to dress these separately and produce more chalcopyrite and blende. The zinc middle products are further treated in the old Thurmhof mill. The mill at Himmelfahrt is open to the following criticisms:

1. The four bins on the top floor are built in connection with the wall, and overload it, also the girders and columns of the building should have been of iron. The successor of Lührig, the engineer Fr. Gröppel of Bochum, employs a tower for his bins, which is independent of the building, and supports the elevated apparatus on iron frame work or masonry piers; the latter or the rock crushers have a height up to 8.5 meters. (See Plate I., Fig. 13.)

In this respect the construction of the mill at Bleicharley, already mentioned, is to be recommended. It was constructed by the Humboldt Machinengesellschaft, in Kalk.

"The roof of the buildings, as well as all apparatus not directly on the foundation, and all launders are carried on an independent framework of wrought iron. This has the advantage that the walls and windows of the building are freed from the vibrations incidental to the great mass of moving machinery. By this arrangement the mill can be better overlooked, and the greatest possible protection against fire is insured." (3 Heft. d. Zeitschr. f. d. B. H. s. l. U. S. W., 1885.)

2. If the slime division of the Himmelfahrt mill is not as complete as those in the later mills built by Lührig, it is not worse than the slime divisions in former mills. The Bilharz percussion jigs are not as well adapted for the treatment of slimes as the Stein and other tables.

3. The waste waters are settled in a small basin, which causes loss of mineral by the overflow. In the new mills of Lührig and Gröppel, the waste waters are cleared in spitzkasten, the slimes washed continuously on Lührig's tables.

The area and space already mentioned, of the Silberau mill at Ems is distributed as follows:

Mine fines division, ...	1,275	s. m. area.
Lead ore division, ...	1,025	" "
Blende "	1,250	" "
Total, ...	3,550	"
Mine fines division, about, . . .	5,200	cu. m.
Lead ore " " . . .	4,500	"
Blende " " . . .	5,300	"
Total, ...	15,000	"

It contains the following apparatus:

Mine Fines Division.

2 large bucket elevators, 2 trommel systems, of each 5 trommels, 4 rotating picking tables, 14 jigs, 4 Linkenbach round tables, 2 pumps and 2 bucket elevators.

Lead Ore Division.

1 coarse roll, 1 fine roll, 2 bucket elevators, 3 separating trommels, of each one sieve, 1 sand classifier, 6 jigs, 2 slime spitzkasten, 3 Linkenbach round tables, 3 pumps.

Blende Division.

1 coarse roll, 1 fine roll, 2 bucket elevators, 5 separating trommels, of each one sieve, 4 jigs, 1 bucket wheel, 3 sand classifiers, 12 ordinary long bumping tables, 1 spitzkasten apparatus, 3 Linkenbach round tables and 3 pumps.

The power required is as follows:

For the mine fines division, ...	36	H.P.
" " lead ore "	45	"
" " blende "	45	"
Total, ...	126	"

against 101 H.P. of the Himmelfahrt mill. The 126 H.P. are developed by two steam engines and two turbines.

The three divisions of the Silberau mill should be capable of treating 150 tons mine fines and 50 tons of roll and stamp ore, equal to 200 tons of ore in ten hours, or the same as the Himmelfahrt mill.

The labor required is given as follows:

Mine fines division, ...	82 men.
Lead ore "	10 "
Blende "	19 "
Total, ...	111 "

including superintendence and engineers, exclusive of mechanics.

To determine the cost of dressing, the figures for one month were taken, in which time the following amount of ore was put through:

Mine fines division, ...	2,063 tons.
Lead and blende divisions, . . .	980 "
Total, ...	3,043 "

of mine fines, roll and stamp ores.

The 980 tons of roll and stamp ore were made to the extent of 23 per cent. by mine fines.

In this month the mine fines division treated only 85 tons per 10-hour shift, and the lead and blende divisions together only 40 tons per 10-hour shift; all told 105 tons of ore.

The cost of dressing amounted to 27 pf. per 100 kg., including repairs and general costs, and 21 pf. without these. (Compare Linkenbach, "Die Aufbereitung der Erze.")

According to Köhler, p. 165, of the previously mentioned technical journal, the cost of dressing at Ems is as follows:

For separating and sorting, ...	0.27	mk. per ton.
Clean picking, ...	0.84	" "
Dressing of mine fines, ...	1.61	" "
" " blende and lead ores, . . .	0.70	" "
Total, ...	3.42	" "

Or per 100 kg. of ore, 0.342 mk. against 0.27 mk. as mentioned above.

The number of hands employed and the cost of dressing at the mills at Freiberg and Ems cannot be compared closely, as the mills do not treat the same class of ores. However, from the figures given it can be seen that the separate dressing of the mine fines down to slimes, and the large amount of transportation necessary between the different divisions at Ems, considerably increase the

cost of dressing, since the work requires more hands. Since at Ems, the ore contains as much blende as galena, the sand and slimes of the mine fines division could be washed with those from the blende division, because the sand and slimes from both divisions are of practically the same composition.

The further advantages of Lührig's floor system, and his arrangement of apparatus in a similar manner in two divisions, for treatment of two classes of ores are as follows:

1. The first cost is less, because the buildings require less walls and roofing. About two-thirds of the interior space is sufficient for the housing of the apparatus. The saving in this respect can be considered as 33 per cent. Further, the problem of driving the machinery and distribution of power is much simpler, as in a large mill all the power can be furnished by one engine. Hence there is considerable saving effected, in less cost of engines and transmission appliances, as well as in repairs, and less labor for tending the same.

2. Less superintendence is necessary.

3. In the floor system, the ore must be elevated just as much as in mills on the level, but the amount of transportation between the divisions is much less, *i. e.*, at Silberau the roll and stamp ores from the picking tables and from the jigs in the mine fines division, must be carried in cars to the other divisions, while in the Himmelfahrt mill the complex ores go directly from the picking tables to the coarse rolls, and the complex jig concentrates fall into pockets beneath the jigs in connection with bucket elevators, which elevate the mineral to the medium and fine rolls and the stamps. The tailings are disposed of more economically in the floor system. This will again be discussed later.

4. The floor system possesses the further advantage over the other, in that much less dump area is necessary. This also affects the first cost considerably. The foundation of the mine fines division and the crushing divison of the Siiberau are on the same level as the shaft mouth (Figs. 1, 3 and 5), so that only about 3 meters of dump height are available. Owing to this the dump, in the course of time, has spread out over great area, making chain transportation necessary. Chain transportation above ground has the disadvantage, aside from great friction, that in the winter it costs considerable to keep tracks free from snow and ice.

In the floor system, tailings and waste rock from the picking

tables can be dumped directly on the dump from a height of about 12 meters. This waste from the tables comprises about 12% of the ore and 15% of the total waste rock and tailings. The tailings from the jigs and tables can be hoisted by elevator 15 meters above the shaft level, as at Himmelfahrt (Fig. 7). Hence there is a dump five times as high here as at Silberau, which is of great advantage for a large dressing works, where tailings accumulate enormously with time.

With hilly topography, Lührig has also applied his floor system in combination with the terrace system, as is represented in Figs. 12, 13 and 14, which are plans of the mills at Laurenburg and Ramsbeck.

In these cases the separation by hand is made on the uppermost terrace.

In both places the ore comes from the mines through tunnels, situated as high as possible upon the hillside, in order to place the mill as high as possible, thus giving enough height for dump. An inclined plane with double track serves to elevate the coal for the boilers and lower the finished products which go to the smelter. The plane has its power furnished by an engine.

At Laurenburg the tailings are also elevated, by means of this plane to the highest point of the works.

The Laurenburg mill is the last of the dressing works built by Lührig, and is considered his best work.

This mill, as regards system, can be looked upon as the greatest and most complete of the present time, and can be compared to the large Central Mill at Clausthal, as more modern. It will therefore be of interest to describe in detail the arrangement of the mill. (Figs. 11 and 13.)

The ore is hoisted from the deep shaft to the middle tunnel and from here hoisted to the upper terrace, on tracks which form in places an inclined plane.

The separation made on this terrace is a new one in ore dressing. It is accomplished by means of a stationary grizzley, a mammoth jaw crusher of 750 mm. jaw width, a shaking grizzley and a large rotating picking table.

The ore is dumped on the inclined grizzley, the mine fines fall through into a hopper, and the coarse, above 150 mm. in size, passing over the grizzley into another hopper, from which it is fed gradually by means of a sliding door into the jaw crusher, by a

laborer. The discharge opening of this crusher is 70–80 mm. and is constructed according to the old model. A little to the side, beneath it, the large round rotating picking table is placed, which is supplied with the ore by means of the shaking grizzley, whose bars are 25 mm. apart. The fines from this grizzley fall into a second hopper and the coarse on the picking table, and is there separated into tails, rich and complex ores, which latter are mechanically swept off the table into a third hopper, for wet dressing.

The ore which can be separated cleanly (Scheiderze) is cobbed next to the rotating table, in the same room. We will again refer to this dry dressing further on.

The wet dressing division of the works is connected with the hand dressing division, that is, with the hoppers below the foundation, by means of a small bridge. The product from these storage bins, consisting of mine fines and crushed ore, is distributed evenly by means of dumping hoppers situated in the roof timbers of the main building, to four jaw crushers, which are connected each with a bumping grizzley.

These crushers are constructed, according to the Kley-Mehler system, having a jaw opening of 440 x 220 mm. and receive the coarse mineral above 25 mm. in size which goes over the grizzley.

The next dressing division below this is divided into two parts which have the same apparatus, as at Freiberg (Pl. IX., d. Sächs. Jahrbuchs, 1890, u. Nr. 25, d. B. u. H. Z., 1891) and Ramsbeck (Nr. 20 d. B. u. H. Z., 1894). Every two crushers have a trommel which is situated with its picking table on the floor next below (compare Pl. I., Fig. 11).

Every picking table is directly in connection with coarse rolls (size 707 mm. x 250 mm.) by means of a shaking grizzley. On the floor below this are situated the medium and fine rolls, two of each in a row. They have the same dimensions as the coarse rolls. The medium rolls receive the fine from the trommels above them in connection with the coarse rolls for a second crushing. Next to the medium rolls, against the wall toward the hill declivity, are placed the coarse jigs, in two rows.

Each one of the medium and fine rolls has a separating trommel in connection with it, which is hung from the ceiling of the lowest floor. The medium jigs are situated on the foundation on the lowest floor. They are placed in two rows and next to them beneath the coarse jigs the storage hoppers for the middle products and tails of the latter are hung.

On this floor are also placed the bucket elevators which elevate the fines from the trommels of the medium rolls to the fine rolls carrying also the complex jig concentrates of 4–7 mm. size. Separate elevators carry the coarser complex jig concentrates to the medium rolls.

For the rich blende ores, which go to the rolls, separate rolls are used, situated outside the row of the medium and fine rolls, but on the same floor.

For treating the poor middle products of the jigs, over 4 mm. in size, 20 stamps are used, situated in an adjoining building on the level of the lowest floor of the main building.

At Freiberg and Ramsbeck the stamps are placed next to the fine rolls on the foundation floor of the main building. The plan at Laurenburg is an improvement on this and to be preferred, as here the stamp mill with its supply bins interferes less, and the space of the first floor of the main building is kept more free from dust; also the connection of this floor with the adjoining slime and sand division is better overlooked.

The sand division is situated on the second terrace (Fig. 11) and is built in two floors. All products of less than 4 mm. of the mine fines and the roll trommels, as well as the stamp slimes, go to this division. Every apparatus division has three one-sieved trommels placed along a common axis, and a sand classifier, for the classifying of this material. This apparatus is situated, with its belonging jigs, on the upper floor.

This arrangement is also an improvement on the sand and slime division of the Freiberg and Ramsbeck works. The middle products of the jigs are carried directly to other jigs on the lower floor (the foundation floor). The tailings from the first mentioned jigs are carried to small spitzkasten where the coarse particles are separated from the slimes. Then the coarse do not go, as almost everywhere, directly to the dump, but are again carried to special jigs. The slimes from the spitzkasten are carried to other spitzkasten, where they are concentrated again; and then treated on Stein tables.

This is an excellent arrangement, by means of which the tails are made as poor as possible and the loss of valuable mineral greatly reduced.

For the concentrating of the various products, as, *i. e.*, the waste slime water from the sand classifiers, and that from the jigs and

tables, there is used a 4-m.-wide spitzkasten apparatus placed outside of the mill on the terrace below that on which the sand classifiers are situated. This apparatus is arranged in several divisions, so that the waste slime waters from the sand classifiers, and the rich waters of the sand jigs, and tables, are allowed to flow into a separate and larger number of spitzkasten than the waste waters from the coarse and middle jigs.

The cleared waters of the spitzkasten apparatus are returned again to the works.

This spitzkasten apparatus forms the connection between the main dressing works and the slime works, which last used to be situated on the Lahn bank in the old mill. (Pl. 1, Fig. 11.)

The concentrated or drained slimes are taken to the slime works, where they are further concentrated in a smaller spitzkasten apparatus and then distributed to Stein tables placed on either side. To the last mentioned, C. Lührig has applied his "connected system," so as to dress the similar middle products as well as the tails of the first tables directly on tables placed below the first. The middle products and tails of the last system of tables are elevated by centrifugal pumps into special spitzkasten apparatus. The slimes gathered in this manner are treated further in the way already mentioned, on 4-part tables.

By these arrangements only the finished products, concentrates and tails are taken out by hand from the hutches, while the middle products and slimes pass continuously through the chain of apparatus. The percentage of mineral won and the percentage of loss are the greatest and smallest possible.

The Laurenburg works possess the following apparatus:

A. Separation.

Fourth Terrace.—1 grizzley, 1 large crusher, 1 shaking grizzley and 1 rotating picking table.

B. Wet Dressing.

Fourth Floor, Main Building.—4 rock crushers.

Third Floor.—2 trommels, of each 6 sieves, 2 round picking tables, and 2 coarse rolls.

Second Floor.—2 trommels, of each 4 sieves, 12 coarse jigs, of each 5 sieves, 2 medium rolls, 2 fine rolls, 2 trommels, of each 3 sieves, 1 pair of rolls for blende, and 1 trommel of 4 sieves.

First Floor, Third Terrace.—11 medium jigs, of each 5 sieves, 2 stamp batteries, of each 10 stamps.

Second Terrace.—4 single sieve trommels, 25 fine sand jigs.

Second Terrace, Sand Division.—2 classifiers, 6 Stein tables, 2 long bumping tables.

First Terrace.—1 large spitzkasten apparatus.

Slime Dressing Division on the Lahn bank.—3 smaller spitzkasten apparatus, 12 Lührig combination tables, of each 4 parts or tables; 14 Stein tables, 1 Schranz table, 2 rotating inclined tables, and 1 bumping table.

The power required is as follows:

For the dry dressing, . . .	35 H.P.	—separate engine.
Main dressing works, . . .	300 "	—compound "
Slime " " . . .	60 "	by the old "

The slime dressing is done, as already mentioned, in the old dressing mill; and next to an almost similar mill for the redressing of old accumulated slimes.

In the new works, omitting the last mentioned slime works, 200 tons of ore can be easily and completely treated in 10 hours by about 130 hands. The cost of dressing per 100 kg. amounts to about half of the cost of the old works which were built in 1860 and abandoned in 1893.

The new Laurenburg works has an area, omitting the dry dressing division as follows:

Main building, ...	465	s. m., inside area.
Sand dressing division, ...	660	" " "
Slime " "	1,800	" " "
Total, ...	2,925	"

The cubic space of these buildings, up to the roof trusses, is as follows:

Main building, ...	6,975	cu. m.
Sand dressing division, ...	4,146	"
Slime, " "	7,400	"
Total, ...	18,521	"

Clausthal Dressing Works.—The Clausthal Central dressing mill was the first and largest mill of the terrace type erected in Germany.

The ore, which is separated into rich, complex and tails in the mine, is elevated through a shaft, close behind the crusher building (Figs. 9 and 10) to the surface, and then evenly distributed over 6 grizzleys with 64 mm. spaces. These grizzleys are in connection with six crushers of moderate size.

The mine fines are sized in 6 special sizing and separating trommels, and the product from the crushers sized in 6 other trommels about 1 m. shorter than the above into sizes above and below 32 mm.

The product over 32 mm. from the crushers and the coarse from the mine fines are then hand picked on long immovable tables, situated in separate adjoining buildings, about 25 and 40 m. respectively from the building where the preliminary dressing is done.

The product less than 32 mm. is lowered from terrace *a* to terrace *b* and from thence to the track *c* where it is conveyed to the Rösch separating trommels in the buildings *d*, situated 160 m. from the preliminary dressing division.

In front of the building *d*, at a suitable depth below it, are placed the fines separating apparatus, for product of less than 4 mm. size.

Adjoining the Rösch trommel division, but on the terrace lower down in building *e* are placed the Rösch jigs. Behind this jig house, in a separate building, are placed the coarse rolls and their belonging rotating trommels. The ore to be crushed of from 17–32 mm. size is fed to one of these rolls, the second set of rolls crushes the complex ore from the picking tables, while the third set of rolls are held in reserve.

The rolls building is about 135 m. from the hand picking rooms necessitating here considerable transportation.

The concentrates from the jigs, 17–32 mm. in size, are hoisted by elevator to the level of the rolls floor. (An elevator is preferable to the bucket elevator used by Lührig if it can be easily installed.)

The medium and fine rolls, placed in building *f*, receive the jig concentrates of 4–17 mm. from the Rösch jig house by means of cars.

One terrace below this in building *g* the medium and sand jigs are placed.

In front of the building *f* and *g*, in a separate building, is the apparatus for dressing fines from the rotating trommels of the mine fines division and rolls. This treats the product of less than 1 mm. in size.

The complex middle products, from the jigs of 1–4 mm. size, are transported by wagons directly to the stamp works on terrace "*h*."

The stamps are in connection with the sand classifiers, sand jigs, slime spitzkasten and the tables. The last are almost entirely rotating inclined tables.

The Clausthal dressing works has the following apparatus:

(*a*) *Main Works.*—6 grizzleys, 6 rotating screens or trommels, of each two sieves; 6 rock crushers, 6 trommels, of each one sieve; 2 immovable long picking tables, 4 Rösch trommel apparatus consisting of each 3 cylindrical trommels of one sieve, arranged step form (half of this apparatus held as reserve); 2 fines separating trommel systems, each consisting of 5 conical and step form arranged trommels of each one sieve; 3 Rösch rolls, 3 trommel systems, of each six trommels; 1 fines separation trommel apparatus for the product of less than 4 mm. produced by the rolls; it consists of 5 separate trommels; 11 Rösch jigs, 4 ordinary hydraulic jig sieves, 6 fine rolls, 6 trommel apparatus, each of 4 trommels of one sieve, and 3 trommels belonging to the middle system. 25 jigs for middle and fine sizes, 8 stamp batteries with each 11 stamps for the hutch work, and conc. 1–4 mm. of the jigs; 8 trommels, 4 sand classifiers, of each 3 boxes; 14 sand jigs, 1 Rittinger double bumping table, 10 rotating round tables for sands, 4 Spitzkasten apparatus, of each 6 spitzen; 8 round tables for the slimes.

(*b*) *Secondary Works.*—1 Trommel, 3 classifiers with 3 resp., 2 spitzen, 11 jigs, 8 round tables, 1 spitzkasten apparatus, 6 round tables.

XI. (*c*) *Stamp Works.*—(For the material from the slime sumps of the main building) 1 stamp battery of 3 stamps, launders, 1 jig, 1 slime ditch, 1 stirring works and 5 round tables.

X. (*d*) *Stamp Works.*—(For the material from the sumps of the secondary works) 1 stirring works and 7 round tables.

XII. (*e*) *Stamp Works.*—(For the blende products of 1 to 5 mm. size), 2 stamp batteries of each, 4 stamps, launders, 4 jigs, 1 slime ditch, 1 stirring works and 3 tables.

Recently the nature of the ore in the veins of the Clausthal district has changed considerably in that almost as much blende as galena is found, while formerly the blende was of subordinate importance, hence the main works were erected to treat principally galena ore. Blende was formerly only a product of the fine jigs

and the stamp works and of the secondary works. To increase the facilities for separating blende ores, changes have been made in the last few years. Some of the jigs have been changed to 3 and 4 sieve jigs and a number of rotating tables have been added.

Aside from this, the former Clausthal stamp works, No. XII. has been changed, as already mentioned, to do this work.

Concerning the capacity of these Clausthal works, about 81,000 tons are treated yearly, or 270 to 275 tons per working day, with a force of 450 men.

The power needed is furnished by a 50 H.P. one cylinder Corliss engine for the rock crusher building; a 100 H.P. Corliss engine (2 cylinders) for the rolls; a 150 H.P. 2-cylinder Corliss engine for the stamp works; a 15 H.P. engine for the lifting of coal and material, etc.; a 12 H.P. locomotive for the No. XII. stamp works; 3 7 H.P. partial turbines and a 45 H.P. Knox turbine to furnish the power for the divisions, below the mine fines department, to the fine jig house; a 15 H.P. Girard turbine for the secondary works: a 30 H.P. Girard turbine for the stamp works building; 5 water wheels for the X., XI. and XII. stamp works.

The main and secondary works (not including the 3 stamp works, and also exclusive of machine, engine and boiler rooms) alone have an interior floor area of 37,000 m.^{2} and a cubic space, figured up to the roof trusses of 19,000 m.^{3}, compared to 2,353 m.^{2} and 18,500 m.^{3} respectively of the Laurenburg dressing works, which also has a much more extensive sand and slime wash.

In comparing the plans of both works, it is seen at once that great progress has been made at Laurenburg in the concentration of the apparatus in small space, compared to the scattered arrangement of apparatus in the older, extensive works.

The connection (automatic) of one apparatus to the other has proved itself of great efficiency as is shown at Laurenburg, Freiberg, Ramsbeck, etc.

In these works, the apparatus which treat middle products, necessarily have considerable room to store the products to be treated. Also the other apparatus is easily approached from all sides, so that these works are in this respect practically arranged.

The capacity of the Clausthal dressing works is small considering the amount of apparatus and force employed, when compared to Lührig's dressing works. At Clausthal, the capacity per shift per man is 0.6 ton crude ore, while at Laurenburg and Ramsbeck

it is about 1.5 tons, or 150 per cent. more. The ore to be dressed is more complex at the last mentioned places than at Clausthal. At Laurenburg the ore contains, beside galena, much blende and siderite. At Ramsbeck the blende and galena are intimately mixed, in part, which makes it very difficult to produce galena poor in zinc, and blende poor in lead. At Clausthal the veins carry about as much blende as galena, and only those of the Rosenhöfer vein carry siderite.

The transportation between apparatus at Clausthal is even more extensive than at the Silberau works. It requires a large working force, and is the chief cause of the large force necessary at Clausthal. The cost of dressing is considerably greater at the last named place than at Laurenburg.

It is the object to prove and show by the foregoing, that the arrangement of apparatus used by Lührig in these large works is practical and economical for the dressing of all ores. It is economical in first cost as well as in cost of dressing. The Laurenburg works probably cost only about one-third as much as the Clausthal works. To show how the first is simplified it is only necessary to mention that it has but 34 trommels (single sieves) against the 78 at Clausthal. The same relation is to be noted in the number of jigs, rolls, etc., particularly the stamps, which will be further discussed in the second part of this paper.

Aside from the small amount of transportation necessary for the middle products, the discharge of the tailings in the terrace and floor arrangement, with their large capacity, is easy and economical.

If at Laurenburg, the road along the Lahn did not exist, and if a new building had been erected for the slime wash directly beneath the large spitzkasten in the main building, the tailings from the coarse and middle jigs could be carried directly to the dump on a common launder, as was done at Ramsbeck by Lührig. Here at Ramsbeck, the jig tailings of over 5½ mm. size were directly discharged on the dumping arrangement (automatically) after passing through a trommel, taking the water out; the trommel being situated at the end of the discharge launder. Recently, owing to the accumulation of tailings, this is not possible, and the trommel discharges the tails into a car which is then discharged at short distances by labor, one man doing all this work.

The tails of the middle and fine jigs and those of the tables are carried to one point by means of waste water, at Ramsbeck and

Freiberg, and from here elevated into bins by means of bucket elevators. From the bins they are loaded into cars and run out on the dump. All this is done by one man.

In these arrangements Lührig has introduced something which, if not new, at least is a great improvement in the art of ore dressing. At Clausthal, where no road interferes as at Laurenburg, the tails have to be elevated from the lower terraces by means of inclined plane with steam power to the top of the dump of the upper works.

Linkenbach at Silberau, before Lührig, in a similar way treated the tails (0 to 30 mm. size) from the jigs and tables in the mine fines division. However the first to use this method were the builders of the still older coal breakers. On Plate XXII. of his work (The Aufbereitung der Erze) Linkenbach shows the method of treating tailings at Ems. The mine fines are here dressed in two similar sets of apparatus. From the jigs of one set, the tails and waste flow through an inclined launder into the bins of a bucket elevator, which dips up material 4 m. below the floor level, then elevates and dumps the material into the inclined launder from the second set of apparatus, and all runs into the sump of a second bucket elevator, which also dips 4 m. below the floor level. This elevator lifts all the material to a trommel which takes the water out. The tails fall into a car, which is then run out on the dump by means of an endless chain. One to two men do this work.

The concentrating of tails at one point is to be recommended for dressing works situated on the level, as it saves considerable labor.

Returning to the terrace and floor arrangement of dressing works it can be said that with a slope of 30° of the ground, it is best to avoid the floor arrangement and use the terrace plan entirely. All divisions, even with such a large plant as at Laurenburg and Clausthal, can be arranged close together, above each other on terraces, if the uppermost building is placed up high enough on the hill (Fig. 15).

At Clausthal, the topography does not afford the slope and hence the terrace and floor combined would have been in place. At Laurenburg (Fig. 11) and at Ramsbeck (Fig. 14) however the rock crusher and rolls floors could have been avoided and been replaced by an intermediate terrace, as is shown in Plate I., Fig. 14, by the dotted lines, if the uppermost building had been placed high enough up on the hill.

In American technical papers, dressing works built on the terrace plan are frequently described.

To this type of dressing works the following can also be counted.

The dressing works of the "Gute Hoffnung Mine" at St. Goar am Rhein. These works were erected by C. Lührig, with great judgment, amongst the old building and ruins of the previous works.

Since the ore from this mine is very difficult to dress into good galena and zinc blende, it will not be uninteresting to describe the arrangement and processes in vogue in these works.

The ore contains the minerals, galena, blende, some chalcopyrite, and considerable pyrite, while the gangue is quartz, slate and a conglomerate (grauwacke). From this ore, the clean pieces of pyrite, and pieces of waste rock are taken out, also large complex pieces for hand picking. This sorting is done in the mine. The rest of the ore all goes to the wet dressing. The coarse sorting and hand picking is much simpler and of less extent, here also, than it used to be.

The old buildings have suffered some change in their foundations, lying terrace-like over each other, to conform them to the new system of dressing. The buildings are erected on the left bank of the Rhine, beginning a little above the foot of the bank, rise on terraces up to the level of the tunnel. The ore is hoisted in the shaft to the level of this tunnel and then transported through it by car and horses to the mill for dressing.

The works are divided into coarse, middle and fine divisions. As in all of Lührig's galena and blende dressing works, here also he introduces an extra set of rolls, trommels and jigs for the rich blende middle products.

Since the reconstruction of the works had to be adapted to the slope of the hill between the former lowest terrace and the tunnel level, and this was found too short, no room was found for storage bins to insure a continuous supply of ore. However, to insure a continuous working a large number of cars are used, a train of these, filled, always being held on the dump in reserve in case the ordinary supply is stopped. The loaded cars are weighed on a scale and dumped by two dumping grizzleys with 25 mm. spaces. On the floor above the fifth terrace are two large rock crushers, which are connected with the trommels by a screen chute and shaking grizzley, also of 25 mm. spaces. Thus they receive all ore above 25 mm. They crush through an opening of 50 mm. the crushed ore falling on a bumping screen with 20 mm. spaces, on which the coarse material, from 20 to 50 mm., is picked off and

sorted. Formerly all the material was discharged unclassified on a rotating picking table. Aside from the sorting on the bumping screen, some picking is done on the screen chute and shaking grizzley on material over 25 mm. in size. The object is to pick out as much pyrite and waste in the sizes of over 20 mm. to 25 mm. from the blende and galena as possible.

The ore not picked from the bumping screen is discharged into two fine rock crushers, which are placed on the fourth terrace. These crushers feed the crushed ore (25 mm. or less in size) to the first preliminary trommels respectively of 14 mm., 8 mm. and 3 mm. sieves, situated in the building above the second and third terraces. The mine fines of less than 25 mm. size also go to these trommels.

The rotating picking table that stands on the same floor with these crushers receives the coarse discharge of the trommels and serves for the complete picking of the 14 to 25 mm. sizes. Next to this table are the coarse rolls, with their foundation on the third terrace, and next to the rolls is a separating trommel of 3, 4, 5 and 6 mm. mesh, which also takes the product of 8 to 14 mm. of the first trommel mentioned. The various sizes produced here go to different five-sieve jigs placed on the second terrace.

For the treatment of the product of the coarse rolls, which is over 6 mm. in size, there is a medium pair of rolls, placed in line with the coarse rolls on the same terrace, but situated a little lower down. The trommel belonging to these rolls also has 3, 4, 5 and 6 mm. sieves, and the material that goes over these returns to the medium rolls. The jigs belonging to this system, 3 in number, are also placed on the second terrace.

A second separating trommel, in line with the other trommel receives the material of from 3 to 8 mm. size of the preliminary trommels. The material that goes through the preliminary trommel goes directly to the fine rolls. These rolls have no special trommel, but their crushed material is elevated by bucket elevators into the trommel in front of it.

For the mixed ores, containing blende, there is, as already mentioned, a separate pair of rolls, with a trommel and two jigs. The concentrates of these, containing mostly galena, are returned, according to size, to the medium or fine rolls.

The further crushing of concentrates, which contain finely disseminated mineral from the last sieves of each jig, of all sizes, is done by the stamp works, of 16 stamps, held over from the old works.

This is situated on the second terrace and belongs to the fines division. In this division there is treated beside the product of the stamps, also the material of from 0 to 3 mm. in size, produced in the coarse and medium divisions. Two trommels, one of 3 mm. mesh, for the separation of the coarse which happens to get in by the supply launders, and the other, of 2 mm. mesh, are placed over the lowest terrace, on which are placed the sand and fine jigs and the Stein tables. In connection with the 2 mm. trommel there is a sand classifier, and with this a slime spitzkasten. All these apparatus are placed in line, the spitzkasten resting directly on the foundation.

The cleaning and settling of the waste waters carrying the tails from the jigs was formerly done in a Lührig "Kratzband" basin, but now sumps are employed. The cleaning of the waste water from the finished and middle products is done in a spitzkasten in front of the jig house. The method of dressing here will be further discussed in the second part of this paper.

The dressing works of the "Gute Hoffnung Mine" has a capacity of 50 to 60 tons per ten hours, employing about 45 hands. The cost of dressing is about 20 pf. per 100 kg. of crude ore. Formerly the number of hands employed was about 90, and the cost was 94 pf. per 100 kg., and with a day and night shift could barely dress one-half of the ore, and do this no better, qualitatively, than now in the new works. Hence, with the continuous process of the new works much greater capacity and a great saving has been accomplished, and the same quality of product produced.

In dressing works situated on level ground, or on a hillside of less than 30° slope, as in Pl. I., Figs. 13 and 17, the rock crushers are placed on stone or brick piers, 8½ m. high, as already mentioned, and the rolls fastened directly to the foundation. The buildings in this way have to carry considerably less load, and can be constructed of lighter material; however, this arrangement necessitates greater amount of transportation of middle products. This disadvantage is obviated by the fact that the crushers and rolls can be made much larger on account of the firm foundations available, size being particularly of importance for rolls, as will be discussed later.

Dressing works of this description are those of the "Pauline Mine" at Nassau, a. d. Lahn (Pl. I., Fig. 17), built by Böhmer &

Krester, in Limburg; "Weiss Mine" at Bensberg, rebuilt by Engineer Gröppel; of the mine "Mathilde" at Hamm, a. d. Sieg, built by M. Neuerburg, in Cologne; and also of the "Bastenberg Mine" at Ramsbeck (Pl. I., Fig. 13), built also by Engineer Gröppel. The system of dressing employed in these mills will be discussed in the second part of this paper.

THE SILVER PLATING OF AMALGAM PLATES FOR GOLD MILLS.

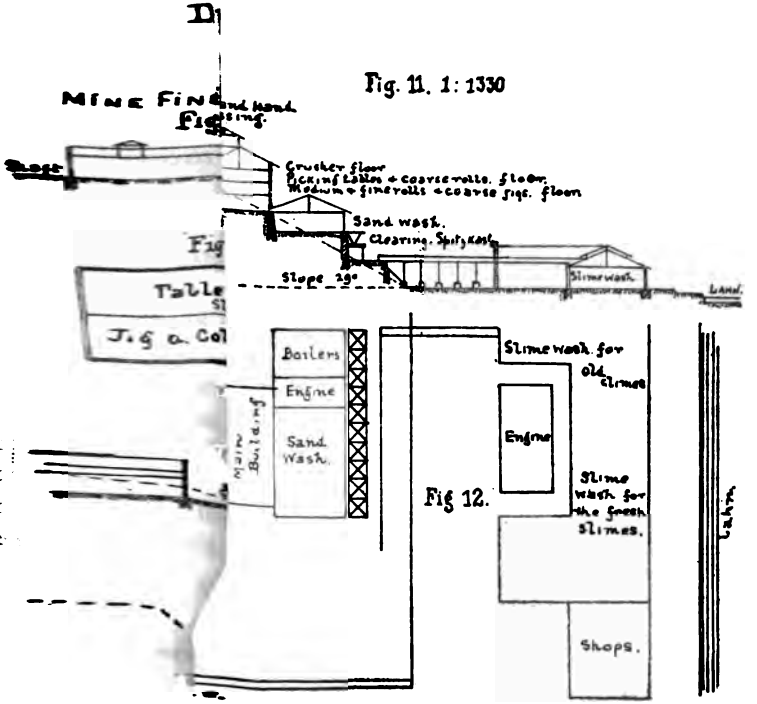
ALLAN JAY CLARK, E.M.

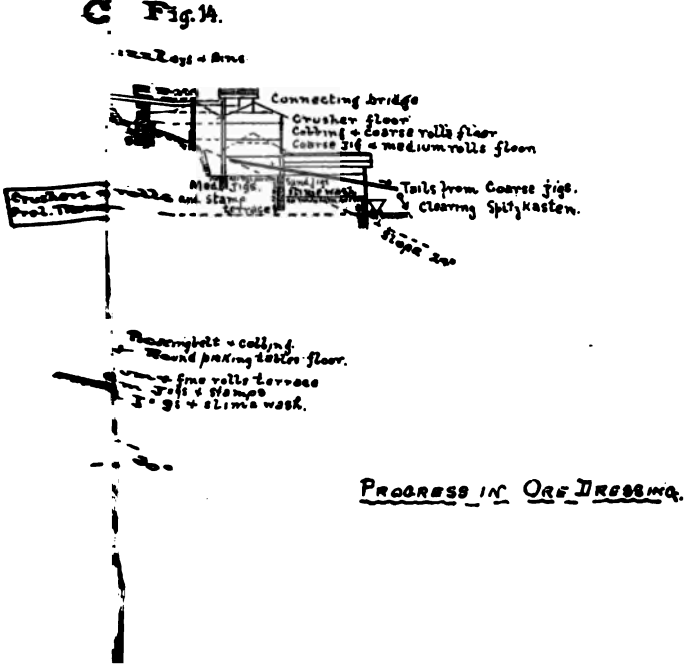
When, during the summer of 1897, the silver-plated amalgam plates of the mill of the Homestake and Highland Mining Companies, at Lead, South Dakota, showed signs of wear, an interesting question presented itself. There were about three hundred of these plates, each 54″ wide, the length varying from 8′ to 12′, the latter size predominating. On account of the probability of a considerable accumulation of values upon these old plates, as well as by reason of the heavy rates of transportation to Eastern points, it was undesirable to ship these plates for retreatment; while their sale to a smelting company would have been equally inadvisable. On the other hand, the decreasing gold recovery as the silvered surfaces became worn was very pronounced, and called for immediate action. It was in consequence decided to do the work at Lead, and the plant here described was accordingly installed.

The process of silver-plating is of course well known, but in his investigation of the subject the writer found that but little of the literature was "up to date," while much was wholly misleading.

Moreover, the particular problems presented by these plates, so long covered with mercury and amalgam, could only be ascertained by experience. As the use of silver plates seems to be steadily increasing in the mills of this country, it may be of use to collect the notes of the operations of the first year and to describe briefly the methods employed and the difficulties encountered.

The Plant.—The operations (with the exception of the preliminary cleaning) are performed in a single well-lighted room, 28′ × 40′, connected with the assay office of the company. In this





PROGRESS IN ORE DRESSING.

room are the motor and dynamo, solution tanks, working bench, painting racks, furnaces and water connections; while a wide platform, extending around two sides of the building, provides a convenient storage place for many of the supplies, and is also used during the warmer months for the painting, thereby giving more room for the operators inside.

In the absence of steam connections, the necessary heat for dissolving the silver for the solution, for heating the cleaning bath of potash, etc., is obtained from a pair of low furnaces placed at the side of the room, the heated products of combustion passing through flues 3′ 6″ wide and 16″ above the floor level. Over part of these flues is a hood, so arranged that it will carry off the nitrous fumes arising from the preparation of the solution, and will also, when the furnace is not in use, be available for the regular work of the chemical laboratory. A 2″ pipe supplies the necessary water. The floor throughout is of cement, sloping from the walls to the center, where a gutter carries the wash water, etc., to the drain. The power is taken from the main circuit of the company —a 110 volt incandescent light line—and drives a 7 H. P. motor, C. & C. make, specially wound, and directly connected with a dynamo, a Hanson & Van Winkle plating machine of 3 kilowatts and 800 revolutions. The foundations of the machines are of cement, raised about 2′ above the floor level. Although these machines are in no way protected from the corrosive action of the acid fumes or from the dust of the assay office, they have required no repairs beyond the reshaping of the dynamo brushes and a renewal of those on the motor.

The tanks are three in number:

1. The solution tank, inside dimensions, 15′ 6″ × 30″, is of redwood, 3″ thick, heavily strapped, and lined with a thick layer of asphaltum. To apply the asphaltum, the tank, after being put together, was laid on its side, the molten asphaltum poured in gradually and ironed smooth. The handling of this large tank is achieved by use of a traveling crane, which gives access to every part of the room, and is used as well for the daily handling of the amalgam plates. The spreading of these tanks when filled with solution is surprising, as much as 2½″ increase of width at the center having been noted. Great care must be exercised, either when filling or emptying, to correct this tendency with the straps. The tanks are set in pits 3′ deep, cement lined, and open to in-

spection on all sides, so that any signs of leakage may be quickly discovered and repaired. As a precaution against leakage, however, the pits are made large enough to carry all the solution in the tank, while at a convenient place a slightly greater depth is provided to pump out all solution so escaping.

2. The so-called stripping tank is similarly constructed and mounted. This tank was built for use in cleaning the old plates, and, proving a failure, has been abandoned.

3. Outside of the building, and below the ground level is a third tank, of pine, 10′ × 5′ × 5′; designed for use in storing the solution when repairs to the solution tank are necessary or when

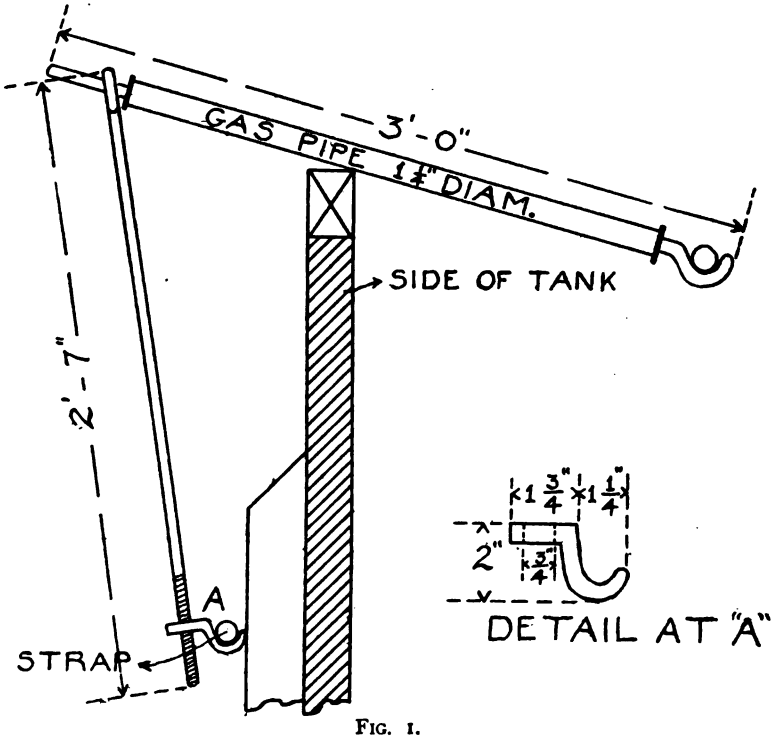


FIG. 1.

the solution has become so fouled as to require filtering. This tank is lined with a simple coating of asphaltum dissolved in turpentine, and as it is not designed to carry the solution for any length of time, its factor of safety is much lower. It is so placed that the solution may be siphoned to it.

Handling the Plates.—Holes are punched at intervals of 2 feet along one edge of the plate, and through these long hooks are passed, which hang from a long cross-bar suspended by a differential pulley from the crane. There are three bars provided to carry the plates while in the solution. When one plate is in the bath, only two of these are used; when two plates are treated they are hung back to back upon the middle bar while anodes are suspended on either side. These bars require a support at the center. To support the center bar, and at the same time to be able to remove one plate from the solution for inspection without disturbing the other (a very desirable feature), the arrangement shown in Fig. 1 is used.

To support the side bars the method is as shown by Fig. 2.

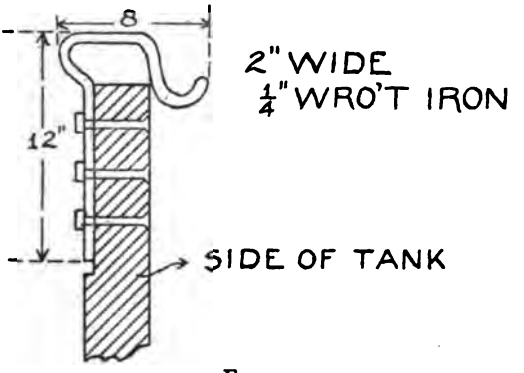


FIG. 2.

Preliminary Cleaning of the Plates.—To secure a proper contact of the silver with the copper surface, a contact which will resist the daily scraping of the amalgamators, the plate must be absolutely clean. The slightest trace of dirt of any sort will cause a flaw in the work. The effect of the usual interfering materials is as follows:

1. "Scale" due to oxidation rolled into the surface of new flakes the silver deposits upon it in a rough, lumpy state, easily scraped off.

2. Thin films of oxide forming if the acid treatment is not quickly followed by a thorough washing and an immediate immersion in the solution. With this, the silver may deposit unevenly, but with so slight a tenacity that it will be washed off by the impact of the wash water applied after removal from the bath. Very similar to the latter is the effect of grease or oil of any kind.

3. *Presence of Mercury.*—This, of course, is only present upon old plates. The deposition of silver upon it simply forms amalgam, which scrapes off at once. To remove the mercury three methods were tried before a satisfactory process was found:

a. Cleaning by hand with steel scrapers, followed by treatment with acid to remove the last traces of mercury. Abandoned as too expensive in supplies and labor, and because of the discomfort attending the heavy fumes.

b. "Stripping" in the tank already mentioned. The plate suspended as an anode in a solution of potassium cyanide, using iron plates as kathodes, and recovering on them any mercury, gold, silver, etc. This attempt was successful in so far as cleaning the plate was concerned, but, owing to the uneven depth of the mercury upon the copper plate, the effect was to "pit" the surface, forming small ridges and hollows over its entire surface. Although a good deposit could be made upon these plates, they failed to amalgamate well, the heavier sands settling in the hollows and effectually preventing the contact of the gold particles with the amalgamated surface.

c. The "stripping" was followed by the use of a power scraper, which was established in one of the mills. It consists of a table, to carry the plate, so mounted upon a track that every part of the plate can be brought under the buff; a buff-wheel, with emery cutting surface, and a small suction fan to collect the particles removed and to discharge them into a box of water, from which they are subsequently recovered. Two men can readily clean three plates in a ten-hour shift, alternating with one another, as the labor is too severe for steady work. The plates come to the plating room in excellent condition for further treatment, and the use of acids and abrasives can be greatly diminished.

On the receipt of the plate from the mill it is set upon a rack and the reverse side painted, in order to "stop off" the deposition of silver upon that side. A solution of asphaltum in turpentine makes a thoroughly good paint, inexpensive, easily applied and quick drying; paraffin may be used, but it is not as good in any way. Asphaltum dissolved in benzine is to be avoided, as it is softened and loosened by the plating solution. The failure of a paint is harmful in two respects: (1) by the loosened particles fouling the solution, and (2) by the waste of silver deposited on the spot left bare. Two coats of paint are applied, and twelve hours are

usually allowed to elapse between the time of the second application and the immersion in the plating bath.

The paint being dry, the final treatment begins. The plate is carried to the working bench, and there treated with one or more chemicals, as its condition may demand. This bench is stoutly constructed of pine and covered with asphaltum, applied in the same way as in lining the tanks. It is sufficiently inclined to drain freely, a gutter at the lower side carrying off the washings. Several small frames of 1″ material, faced with rubber strips, are so placed as to carry the plate, allowing all washings to run freely beneath it and protecting the paint. Since finishing work for a time, a hood has been built over this bench, and a small fan will be driven by a line of shafting from the motor to assure more perfect ventilation. The solutions, or "dips," are kept in earthenware jars of 12- and 20-gallon capacity. When using, these jars are placed under the drain from the bench, and the "dip" is poured from earthenware pitchers. Rubber gloves protect the operator's hands.

The various cleaning operations, as already stated, are used as the condition of the plate requires. They are (1) scouring with sand or pumice stone. Chiefly resorted to in removing scale. (2) acid dip—equal parts of nitric and sulphuric acid, with 1 to 5% of hydrochloric—to remove oxides and any mercury which may remain. The effect of the sulphuric acid seems to correct the too violent action of the nitric acid upon the copper, an action which results in the "pitting" of the smooth surface. (3) Potash or soda lye—a strong solution preferably used hot, to remove grease, etc. This solution is kept in an iron kettle, and is applied with a mop. (4) Cyanide of potassium. (5) Finally, cyanide of mercury is added, and without washing the plate is immersed in the silver bath. This tends to improve the adherence of the deposit.

Preparation and Working of the Solution.—The bath used is a solution of silver chloride in potassium of cyanide (the double cyanide of potash and silver), with an excess of potassium cyanide present. The action of the current is to deposit silver at the kathode while the liberated potassium cyanide replenishes the solution by dissolving silver from the anode. The excess of potassium cyanide insures a faster and more even working. In preparing the solution, granulated silver, .999 fine, is dissolved in nitric acid, the silver deposited as chloride by the addition of salt, washed and transferred to a large filter, placed above the tank.

The cyanide is dissolved directly in the tank and the solution pumped through the filter until the silver chloride is completely dissolved.

For the particular work under consideration, good results may be obtained within a considerable range of strengths of the solution. A solution carrying 2½ oz. silver and ½ lb. cyanide to the gallon gave very satisfactory results. Care must, of course, be taken to have sufficient anode surface, that the silver content may not be impoverished. From 15 to 20 anodes, each ¼″ × 6″ × 3′–0″, were used per plate. The ordinary range of temperature does not affect the work. Presence of insoluble matter becomes troublesome after a time, and a filtration every six weeks is beneficial. Amperage and distance between anode and kathode affect the rate of deposition; voltage determines the character of the deposit and must be fairly constant. With a solution of the strength described, and a distance of 16″–17″, a current of 1½ volts is ample; with 2 plates, 10″–12″ apart, 2 or 2¼ volts may be carried. The rate of deposition is .35 to .50 oz. per sq. ft. per hour. The position of anode surface with relation to kathode surface must also be considered, as the current follows the least resistant road through the bath, and the placing of one or more anodes beyond the end of the kathode will result in a too rapid deposition on the edges of the plate, with its attendant evil, a "hard" or "burned" deposit—*i. e.*, a deposit showing a slightly yellowish coloration instead of the dead white of proper working; rather lumpy, but thoroughly adherent. A slight excess of voltage shows a similar effect; a great excess emphasizes it largely, the deposit forming in a heavy powdery crust.

A new solution does not work as well as an old one; time is required to secure an even mixture of the various compounds. After a day's work the solution is stirred, with this object in view. Small additions of ammonia and ether seem to help to correct this tendency of a new solution, but their use is rarely necessary. It is highly desirable to remove the plates for inspection after the current has acted for ten or fifteen minutes. Any unclean spots or any surfaces upon which the plating is imperfect are shown, and a few minutes' rescouring may remedy the evil.

When the work was nearly finished, and the plant was being prepared for a shutdown of several months, an effort was made, by use of a greatly diminished anode surface and a low voltage, to remove as much silver as possible from the solution.

Analyses.—To insure good work, careful watch must be kept of the solution, and silver or cyanide added from time to time, as required. The methods of analysis used are briefly outlined below. They were selected after a trial of several others as being rapid and sufficiently accurate.

For Silver.—25 cubic centimeters of solution are taken; to this hot, concentrated solution is added at once an excess of alkaline sulphide (preferably K_2S_2). Lime is added to settle the precipitate quickly; then filter, dry, remove the precipitate to a scorifier; burn the paper and add it to the scorifier with some test lead; scorify and cupel, observing the usual precautions as to heat.

For free K (CN).—The usual $AgNO_3$ titration method is used, with KI as an indicator. It has been the writer's practice to use a solution of 6.535 grams of $AgNO_3$ per liter, a strength used in the cyanide process, and to employ a set of tables to calculate the value, rather than to prepare a special solution for this work. With this standard, 10 cc. of solution are taken, diluted to 200 cc. and to 10 cc. of the mixture titrated.

Recovery of Valuable Products.—The scrapings from the buff are cleared in a Knox pan with mercury. The resulting amalgam is squeezed, retorted and melted into small bars, which are added to the regular bullion from the mills. They make up about 7% of the total weight of bullion. About 200,000 ozs. of amalgam were recovered from 300 plates, which yielded after retorting and melting over 14,000 ozs. of base bullion, of a composition ranging from 14% gold, 14% silver and 72% copper to 5% gold, 23% silver and 72% copper. The scouring sand, etc., is settled in a box placed in the drain, and is returned to the mill. It is not in a proper condition for this treatment, however, and it would be better to sell to a smelter. A small additional amount was recovered from this source. Old and worn anodes are remelted, cast into bars and hammered into shape for a second use.

The cost of the operation, including labor and supplies, need not greatly exceed the cost of the silver. The work of refitting all the mill with new plates occupied about six months, during much of which time four plates were plated daily with two ozs. of silver to the square foot. It was considered advisable to have a plant larger than the actual needs of the company, as the time during which the plant lies idle is more than made up for by the increased recovery of the mills when the plates are in good

condition. Moreover, when the cost of the building is included, the additional expense incurred by doubling the capacity should not be over 20%. It would not be wise to limit the width of the tank too closely; slight irregularities in the solution might demand greater distance between anode and kathode to insure good work.

A BRIEF REVIEW OF THE TITANIFEROUS MAGNETITES.*

By J. F. KEMP.

FINLAND.

Titaniferous iron ores analogous to those of Norway are casually mentioned by several authors as abundant in Finland. The writer has not succeeded however in locating extended descriptions of them.

NORWAY.

The titaniferous ores of Norway are the most widely known of all the world's deposits of this character and have been the most extensively utilized. They are situated in an area of igneous rocks in the extreme southwest corner of the Scandinavian peninsula and near the two towns, Ekersund and Soggendal. The local geology is almost identical with that of the Adirondacks and with the Norian areas of Canada, and no more striking parallelism of formations can be traced in any other two widely separated districts of the globe.

The eruptive rocks at Ekersund and Soggendal have been recently described in great detail by C. F. Kolderup.† They are regarded as of age later than the Upper Silurian and embrace the following series, the oldest being placed first.

1. Labradorite-rock and labradorite-norite together with a few ilmenite dikes or segregations.‡

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* Concluded from the July number, page 356.

† Carl Fred. Kolderup, Die Labradorfelse des Westlichen Norwegens. Bergens Museums Aarbog, 1896, No. V., Bergen, Norway.

‡ It is not easy to find a good English term for these basic segregations that are original with the intrusion and formed in it, while still molten, by magmatic rearrangement.

2. Norite, gabbro-norite, quartz-norite and pegmatite-norite.
3. Monzonite and banatite (*i. e.*, syenitic and dioritic rocks).
4. Ilmenite-norite and ilmenitite.
5. Augite-granite and granitic aplite.
6. Diabase, diabase-porphyrite, olivine-diabase.

This will be recognized as very much the same series as is set forth for the Adirondacks in the sketch of the geology in the July number, pp. 341, 342, with the exceptions that the names under 3 and 4 have not been used in this form and that the excessive dynamic metamorphism in the Adirondacks has led to the calling of many of the rocks "gneiss," until their eruptive nature could be demonstrated.

In Norway the titaniferous ores are found in the labradorite rock (or anorthosite) and in the intrusions of rocks related to norite, but so rich in ilmenite that they are called ilmenite-norite and ilmenitite. In the labradorite-rock they form masses of somewhat lenticular or elongated outline, which lie in parallel series in the midst of phases of the anorthosite which are enriched with bisilicates and the ore, but which shade out into the normal anorthosite. They are regarded as ultra-basic segregations in the original and still molten magma, and are analogous to the Adirondack deposits at Lake Sandford.

Ore bodies of this type also occur in norite and in the same general region as those in the labradorite rock. Their origin is regarded as the same, and the rock immediately associated with them is also the same.

In the following analyses Nos. I.–V. are of ores in the labradorite rock; No. VI. of one in the norite. I., II., IV., V. and VI. are from Kolderup's paper, pp. 168–175. No. III. is from J. H. L. Vogt, Om Dannelse af Jernmalmforekomster (On the formation of iron ores), Norwegian Geological Survey, 1892, 25. It is quoted by Kolderup but incorrectly.

	I. Laxedalen.	II. Blaafjeld.	III. Blaafjeld.	IV. Storgang.	V. Fröitlef.	VI. Aarstad.
TiO_2	38.—	41 67	46.31	45 22	45.29	16.94
FeO	——	——	32.43	42.69		15.63
Fe_2O_3	——	——	12.03	12.40		67.63
SiO_2	1.50	——	——			
CaO	0.08	——	——			
MgO	——	——	5.14			
Total			95.01			100.20
Fe	47.58	39.	33.64	41.88	41.21	56.49

These ores all run high in TiO_2 except No. VI. and resemble in this respect the Canadian rather than the Adirondack occurrences. No. VI. is analogous to the latter but it had a little copper pyrites. All the above ore bodies are near Soggendal. Six or eight miles to the northwest is the Ekersund district which has been described in especial fulness by Professor Vogt,* who has also given many details regarding Soggendal.

The ore-bodies are interpreted as true dikes by Vogt and by Kolderup. They come off sharply from the wall rock and show no transition to it whatever. They contain inclusions of the wall rock precisely as if pieces had been broken off and caught up in an intrusion. The ores have been chiefly found along the course of a huge dike of olivine diabase, known as the St. Olafs dike, but with it they have no connection as they are older. The following analyses illustrate the composition of the ore and are taken from Vogt's paper, pp. 25, 26.

	I.	II.	III.	IV.
TiO_2	41.75	34 50	44.05	43.78
Fe_2O_3	22.11	29.00	18.71	20.03
FeO	31.01	27.00	34.17	32.31
MnO	0.28	——		
SiO_2	0.60	——		
CaO	0.55	2.00		
MgO	3.15	4.07	3.04	3.94
P_2O_5	0.015	1.268		
S	tr.	0.287		
	99.95	98.13	99.97	100.06
Fe	40.08	41.30		

The analyses exhibit several of the characteristic features of titaniferous ores. The TiO_2 is high. MgO is high. At the same time the SiO_2 is so low, and the totals are such that almost no Al_2O_3 can be present (thus ruling out spinel), and one is forced to conclude that some of the MgO must replace FeO in the ilmenite.

Analysis I. shows the usual amounts of phosphorus and sulphur, but analysis II. shows that both may be quite high in particular cases. Vogt also cites the general ranges of six earlier analyses, as 39.16–51.30 TiO_2, with a mean of 43.98, 29.25–8.87 Fe_2O_3 and 27.32–39.83 FeO (37.19–41.77 Fe with a mean of 40.29); 0.40–

* J. H. L. Vogt, Om Dannelse af de vigtigste i Norge og Sverige representerede grupper af Jernmalmforekomster (On the formation of the most important types of iron ores represented in Norway and Sweden). Christiania, 1892, p. 14.

2.31 MgO; 0.21 MnO; .12 and .34 Cr_2O_3; finally a little cerium and yttrium.

Vogt mentions in an appendix to his paper that basic segregations consisting of ilmenite and enstatite and rich enough in iron to form a lean ore, occur at Langoen and Gomoen in the Krageroe fjord. The wall rock is olivine hyperite and the origin is similar to that already set forth for the Ekersund ores. David Forbes* has given a few details of small lenticular masses of these ores, in metamorphic schists, on some small rocky islands called Dybsunds Holmene, in Krageroe fjord. They were weakly magnetic and afforded the analysis given under I. Another sample from the Gullaxrud mine, Eger, gave the results in II. T. C. Thomassen,† as cited by Vogt, has described ores in true gabbros at Skonevig, in the Matre and Akre fjords. W. M. Bowron‡ has cited the analysis under III. as representing the ore smelted for some years by the Norwegian Titanic Iron Co. at Norton near Stockton-on-Tees, England. The ore was imported from Norway.

	I.	II.	III.
TiO_2	15.10	7.10	39.20
Fe_2O_3			18.59
FeO			30.00
MnO	0.14	0.48	0.60
SiO_2	19.90	28.10	5.70
Al_2O_3	2.61	1.70	2.89
CaO	2.11	3.55	
MgO	1.88	3.98	2.80
S	0.19	0.59	
P	none	0.77	
Fe	42.04	38.89	99.78

Nos. I. and II. are moderate in TiO_2 and high in SiO_2: the presence of quartz is evident, and indeed the ore is stated by Forbes to contain quartz and hornblende. This gives it important differences from the normal type. No. III. apparently came from the Ekersund-Soggendal district.

* David Forbes, On the Composition and Metallurgy of some Norwegian Titaniferous Iron Ores, Chemical News, Dec. 11, 1868, p. 275. See also Idem, Nov. 22, 1867.

† T. Ch. Thomassen, Geologiske undersogelsen pa Folgefons halvö; Nyt Magazin for Naturv., XXIV., 287.

‡ W. M. Bowron, the Practical Metallurgy of the Titaniferous Ores, *Trans. Amer. Inst. Min Eng.*, XI., 159, 1883.

SWEDEN.

The titaniferous ores of Sweden are different in their geological relations from those of Norway, but are in part very similar to the Cumberland Hill occurrence in Rhode Island, and the parallelism is no less striking between the two, than between the Norwegian and those of the Adirondacks and Canada. The principal Swedish locality is at Taberg* in Smaland in the southern part of the peninsula. A great boss of basic igneous rock, about one and one-half kilometers long, one-half kilometer broad and 130 meters high above the surrounding country, is found in granite gneiss, with the long axis conformable to the foliation. In the central part of the ore is a mixture of titaniferous magnetite and olivine as was first demonstrated by A. Sjogren† in 1876, who called this rock mass magnetite-olivenite. With these two minerals a few shreds of biotite are intermingled. Passing outward toward the rim, as has been shown by Törnebohm,‡ plagioclose is found in increasing amount, with the long dimensions of the crystals parallel with the contact. The rock becomes a type, known in Scandinavia as hyperite, which Vogt describes as a variety intermediate between gabbro and diabase. The composition is shown by analyses given below, but the

	I. Taberg.	II. Laanghult.	III. Iglamala.	IV. Ulfö.	V. Alnö.
SiO_2	21.25	14.95	16.17	24 74	6.88
Al_2O_3	5 55	8.95	5.34	6.99	1.42
Fe_3O_4	43.45	52.85	Fe_2O_3 35.20	24.58	40.75
			FeO 23.22	21.86	26.59
MnO	0.40	0.30	0.46	0.69	1.13
CaO	1.65	1.80	1.84	2.88	1.98
MgO	18.30	10.25	7.56	9.23	8.70
TiO_2	6.30	8.50	7.14	9.53	10.65
P_2O_5	0.13	0.12	V_2O_5 0.40		
			0 07	0.07	0.002
S	0 01	0 02	1.02	0.01	0.04
H_2O and loss	2.60	1.40	0.40	. .	1.33
	99 64	99.14	98.42	100 61	99 47
Fe	31 45	38.25	42.70	34.20	49.26
Cu	0 02	. .	tr	0.03	

* Literature on next page.

†A. Sjogren, Ueber das Eisenerzvorkommen von Taberg in Smaland. Geol. Fören. in Stockholm, Forhandl., III., 42–62, 1876, and VI., 264, 1882. Neues Jahrbuch, 1876, 434.

‡ A. E. Törnebohm, Om Taberg i Smaaland och ett par dermed analoga jernmalmförekomster. Idem, V., 610–616, 1881. Neues Jahrbuch, 1882, II., 66.

segregation of basic minerals at the core, rather than at the rim, which latter is a common experience elsewhere, is remarkable.

Taberg is the largest example of the kind in Sweden, but Törnebohm mentions other smaller and leaner, but otherwise strictly analogous cases at Langhult, Ransberg and between Jöhnköping and Hjo. Vogt cites still others at Iglamala, Illfö and Alnö.

These analyses are all taken from Vogt's "Om dannelse af Jernmalmforekomster," p. 35. They will also be found in the Zeitschrift für prakt. Geologie, January, 1893, p. 9. The ores from Ulfö and Alnö are in olivine-diabase, but there is but slight difference between this and the so-called hyperite.

The analyses, except perhaps the fifth, are all of very low grade ores, so far as iron is concerned. The TiO_2 is in very moderate amount and the other oxides indicate an abundance of ferro-magnesian silicates in the ore.

A peculiar variety of titaniferous ore body was simultaneously described in 1893 by W. Peterson * and H. Sjogren.† The ore consists of titaniferous magnetite and ilmenite, mixed with green spinels, regarded as hercynite or pleonaste. Olivine and pyroxene have been detected and some questionable chlorite, pyrrhotite and apatite are accessories. The wall-rock is determined by both observers, who, however, differ in a few minor points regarding the minerals present, as a metamorphosed gabbro. Plagioclase and green hornblende, with some brown biotite are the chief minerals; garnet and epidote also occur. An analysis afforded the following:

SiO_2	4.08	Fe_2O_3	33.43	CaO	0.65	P_2O_5	0.016
TiO_2	14.25	FeO	34.58	K_2O	0.15	Fe	50.29
Al_2O_3	6.40	MnO	0.45	Na_2O	0.29		
Cr_2O_3	0.20	MgO	3.89	H_2O	1.32		

This analysis confirms much that has been said of the probability of spinel in previous analyses. The description of the ore proves it to be extremely like the ores occurring in the norite of the Cortland series of eruptive rocks near Peekskill, N. Y. These were recognized as extremely rich in alumina as far back as 1874 by

* W. Peterson, Om Routivara järnmalmsfält i Norrbottenslän. Geol. Fören. Förhandlingar, XV., 45–54, 1893. (On the Routivare Iron-ore locality in Norrbottensland.)

† Hj. Sjogren, En ny jernmalmstyp, representerad af Roetivare Malmberg, Idem, 55. (A new iron-ore type, represented on the Routivare ore hill.) Ytterligare om Routivare jernmalm, Ibid., 140–143. (Further notes on Routivare iron ore.)

J. P. Kimball,* who described them and who interpreted the ore as a mixture of magnetite and anhydrous oxide of aluminum. The mineralogy was correctly determined by G. H. Williams † by means of thin sections to consist of magnetite, pleonaste, and more or less hypersthene, feldspar, biotite and garnet. Similar deposits in the same series of eruptives, but in other portions, are so rich in corundum that they are being dug for an abrasive.

Kimball gives the following analyses of the iron ores :

	I.	II.	III.	IV.	V.	VI.
FeO }	45.86	——	21.14	18.49	17.92	
Fe_2O_3 }			25.86	28.21	28.70	
FeS_2	2.63	——				
MnO	0.55	——				
Al_2O_3	39.36	41.28	45.58	36.46	34.47	39.23
CaO	0.47	——	——	——	——	——
MgO	7.18	——	——	——	——	——
P_2O_5	0.22	——	0.16	0.09	0.16	
SiO_2	0.51	0.32	1.13	1.04	2.88	1.17
TiO_2	2.41	3.90	3.88	3.52	4.41	3.824
H_2O	1.18					
Fe	34.44	35.82	34.54	34.13	34.03	34.59
P	0.09	——	0.07	0.04	0.07	0.067
S	1.40					

Except in the last analysis the titanium is low, but the alumina is extraordinary and with the high magnesia and low silica, clearly shows the presence of spinel and doubtless some corundum. The occurrence is, however, very like the one at Rqutivare.

Masses of titaniferous ore of inconsiderable size have been described by Högbom,‡ as occurring on the island of Alnö in association with certain basic derivatives or phases of nepheline-syenite. This association is peculiar to this locality so far as yet known.

Alno is a small island on the 62° 30′ parallel of latitude, and just off the east coast of Sweden, in the Gulf of Bothnia. The nepheline-syenite penetrates gneiss and contains much included and intimately involved limestone. It exhibits several phases, from some quite acidic to others decidedly basic, and it has very curious and interesting basic dikes, which evidently are genetically con-

*J. P. Kimball, *American Chemist*, IV., 321, 1874. *Trans. Amer. Inst. Min. Eng.*, IX., 19, 1880.

†G. H. Williams, *Amer. Jour. of Sci.*, Feb., 1887, 194.

‡A. G. Högbom, Uber das Nephelinsyenitgebiet auf der Insel Alnö. Geol. Fören. Förhandl., XVII., 100, 214, 1895. Neues Jahrb., 1896, I., 252.

nected with its original magma. The masses of ore are of small size, as ores go, some two thousand tons, perhaps, having been mined. They occur as basic segregations in the more basic phases of the syenite. In the following analyses No. I. is of the ore, and is by A. Tamm (Analyser jernmalmer, 1890, p. 6, as quoted by Högbom, p. 153), and the other is by P. J. Holmqvist, for Högbom. The last is a basic phase of rock rather than an ore, as is shown by the lime and phosphoric acid.

	I.	II.
SiO_2	3.10	6.32
TiO_2	12.14	4.57
Al_2O_3	tr.	2.10
FeO	8.95	15.80
Fe_3O_4	64.38	Fe_2O_3 23.12
MnO	1.15	0.51
CaO	2.30	26.26
MgO	8.00	1.92
S	0.07	——
P_2O_5	tr.	16.47
CO_2	——	tr.
	100.09	98.07
Calculated Fl.		1.50
		99.57

In No. I. the percentage of MgO is remarkable, considering the low SiO_2 and the absence of Al_2O_3. It would seem to indicate a magnesia-iron spinel, MgO, Fe_2O_3, or chlorospinel. The second analysis is evidently of a basic segregation very largely apatite.

AUSTRALASIA.—NEW ZEALAND.

New Zealand is thus far the only Australasian colony in which the titaniferous ores have attracted attention, but their local abundance and the neighborhood of coal and limestone have led to some more or less experimental efforts to smelt them. All the deposits recorded are in the nature of beach sands and they closely resemble the titaniferous sands at Moisié on the St. Lawrence river, Quebec, described on p. 331, of the July number of the QUARTERLY, 1899.

The largest deposits are in the province of Taranaki, in the southwestern corner of the northern island. The sands occur for a stretch of thirteen miles near the town of New Plymouth. They have been proved to a depth of 14 ft. and have been found by dredging at a distance of 3 miles from the land. The titaniferous

magnetite is immediately concentrated by the beating of the waves of the sea against cliffs of sand which contain it, and by the sediments washed in by the rivers, but its original source is recognized to be in the eruptive rocks of Mt. Egmont, a volcanic group lying inland in the province of Taranaki. The following analyses have been published. The first is by Sir James Hector and is taken from the paper by E. Metcalf Smith cited below; the second is by Richard Smith, and will be found in the discussion of the paper by E. Metcalf Smith, in the original reference.

	I.	II.
Fe_2O_3, FeO	82	
Fe_2O_3		52.88
FeO		29.60
TiO_2	8	8.14
Al_2O_3		0.90
MnO		0.48
MgO		0.40
SiO_2	8	3.80
CoO		tr
P_2O_5		none
S		none
Water and loss	2	——
	100	99.80

The analyses afford an interesting confirmation of the general characters of these ores which have been earlier emphasized. The absence of lime would make the presence of pyroxene in notable amount improbable and the magnesia and alumina would then be naturally combined in spinel. The silica is probably quartz. The trace of cobalt makes one wonder if nickel is not also present, and one can but wish that a determination of chromium had also been made. The absence of phosphorus and sulphur is in line with the usual although not invariable experience. E. Metcalf Smith describes the experiments made to smelt the sands. They were puddled with clay, and put through the furnace as bricks. A malleable pig, as is usual with titaniferous ores, was obtained and from it a high grade of bar iron was made.*

* E. Metcalf Smith, On the Treatment of New Zealand Magnetic Iron Sands, *Journal of the British Iron and Steel Institute*, 1896, I., 65. In the discussion of the paper a citation regarding the smelting of the sands is given as follows: W. B. Bassett, *Trans. of Institute of Mining and Metallurgy*, Part I., 108, but it is not accessible to the writer. The paper by E. Metcalf Smith is reprinted without the discussion in the *Engineering and Mining Journal*, June 13, 1896.

Titaniferous sands are also known in very large amount on the western coast of the southern island at Hoikitika, Westland. They are said to contain 75% of magnetite and as they are gold-bearing they are quite extensively washed for the yellow metal.*

ASIA.—JAPAN.

Deposits of iron-bearing sands have been worked from a very early period in Japan, but only in one case has the writer been able to find an analysis, and that was of a sand which is artificially concentrated from the surface decomposition products of granite. The locality is in the province of Harima, and from 2 to 6% of the crude material is ore, the average being nearer 2 than 6. On analysis a sample of concentrates yielded:

Quartz.	TiO_2.	FeO.	Fe_2O_3.	MnO.	CaO.	MgO.	Total.
12.1	6	25.2	56.28	tr	.30	tr	99.80

This would correspond to metallic iron 58.49.†

Professor H. S. Munroe‡ gives some details of the beach sands near Yamakushinai, Iburi province, and Kobui in Oshima province, both on the island of Yesso. They are said to be extensive and to contain titanium.

* Annual reports upon the mining industry of New Zealand are issued by the government but deal more particularly with gold. Sir James Hector has published a "Handbook of New Zealand" which has passed through several editions. F. W. Hutton has published a "Sketch of the Geology of New Zealand," *Quar. Jour. Geol. Soc.*, XLI., 195. L. de Launay has given an abstract of the mineral resources in "Les Richesses minérales de la nouvelle Zelande," *Annales des Mine*, 9th series, V., 1894, 523. The "Transactions of the New Zealand Institute" contain papers on the local geology, but the only one which relates to the iron sands, so far as discovered by the writer, is by E. Purser, "Iron from the titaniferous sand of New Zealand," XXVIII., 689, 1895. The richest sands are said to be at the mouths of rivers, on the north sides. The best of all are at Waiwaki, in Taranaki province, and at the mouths of the Awakino and Mokan rivers, in Auckland. Eighty-eight to ninety per cent. of the sand is magnetite. Briquettes were made of it and some experimental pig iron was produced, of which an analysis is given.

† D. Sevoy, Les procedes de traitement der minerai de Fer, et du minerai de cuivre au Japan. *Annales des Mines*, VI., 1874, 345.

‡ H. S. Munroe, The Mineral Wealth of Japan. *Trans. Amer. Inst. Min. Eng.*, V., 268. See also B. S. Lyman, on the Minovi iron region, with description of processes of working. *Geological Survey of Japan*, Reps. of Progress, 1878–79, 58.

REDUCTION-ROASTING—ITS VALUE FOR ARSENIC-EXPULSION FROM COPPER ORES AND MATTES.*

BY EMILIUS W. SCHERR, JR., A. M.

The object of the work here described was to ascertain to what extent arsenic is expelled from a previously well-roasted copper matte by a subsequent *reducing-roast* with charcoal, the arsenic at the start being in combination with iron as arsenopyrite (FeAsS).

Several experiments of this nature were made in 1889 by Mr. Richard Pearce, of Argo, Colo., the only essential difference being that the material he used was enargite (Cu_3AsS_4) which contained its arsenic in combination with copper. Mr. Pearce's experiments showed that carbon under such conditions did not expel arsenic, so that in our own work arsenopyrite was chosen to see whether a different state of combination of the arsenic would have any effect on its elimination by carbon. Mr. Pearce described his work in the course of his Presidential Address before the American Institute of Mining Engineers, wherein he said: "I have found by experience that it is not an easy matter to get rid of arsenic from an ordinary arsenical ore by roasting and in order to test the efficiency of the coal added in the latter stage of roasting for the elimination of arsenic as recommended in certain works on copper smelting—I have made the following experiments."

These we have summed up as follows: The ore used contained 3.26% As—and was a mixture of chalcopyrite ($CuFeS_2$), bornite (Cu_3FeS_3) and enargite (Cu_3AsS_4), the roasting was carried out in a muffle, on fine ore, and "the conditions (oxidizing) were as perfect as it is possible to obtain."

Experiment 1.—The ore when simply dead-roasted showed the least removal of arsenic—the loss being only 23.31% of the total original quantity.

Experiment 2.—The treatment that gave the most thorough removal of arsenic (a loss of 32.8%) was the following: To the ore, dead-roasted as above, and while still hot, there was added 10% of fine coal, the roasting being continued until all the coal was burned out. (This likewise was the general plan adopted for our own experiments.)

* Thesis submitted in partial fulfilment of a minor subject in metallurgy for the degree of Doctor of Philosophy. *Columbia University, May, 1899.*

Experiment 3.—An intermediate efficiency, giving a loss of 27.6% As, was obtained by mixing with the ore 10% of fine coal and then roasting thoroughly.

It will be seen, on comparing 2 and 3 with 1, that the addition of coal actually gave a greater percentage elimination of arsenic, but the gain was a slight one, the average increase due to coal being, according to Mr. Pearce, only 6.02%; he therefore says: "The result of my experiments would indicate that the reducing action of coal on *arseniate of copper* is not so active as is generally supposed. Indeed, it is a question to my mind, whether there is any action of importance, or whether reduction can take place except at the melting point of arseniate of copper, which is beyond the temperature necessary for roasting. It is, of course, possible that arseniate of copper is reduced to arsenide of copper, at a roasting temperature in contact with coal, without producing any sensible loss of arsenic."

We cannot help noting here that Mr. Pearce assumed all through that he was trying to reduce simply arseniate of copper—and not arseniate of iron, or indeed the arseniate of any other metal.

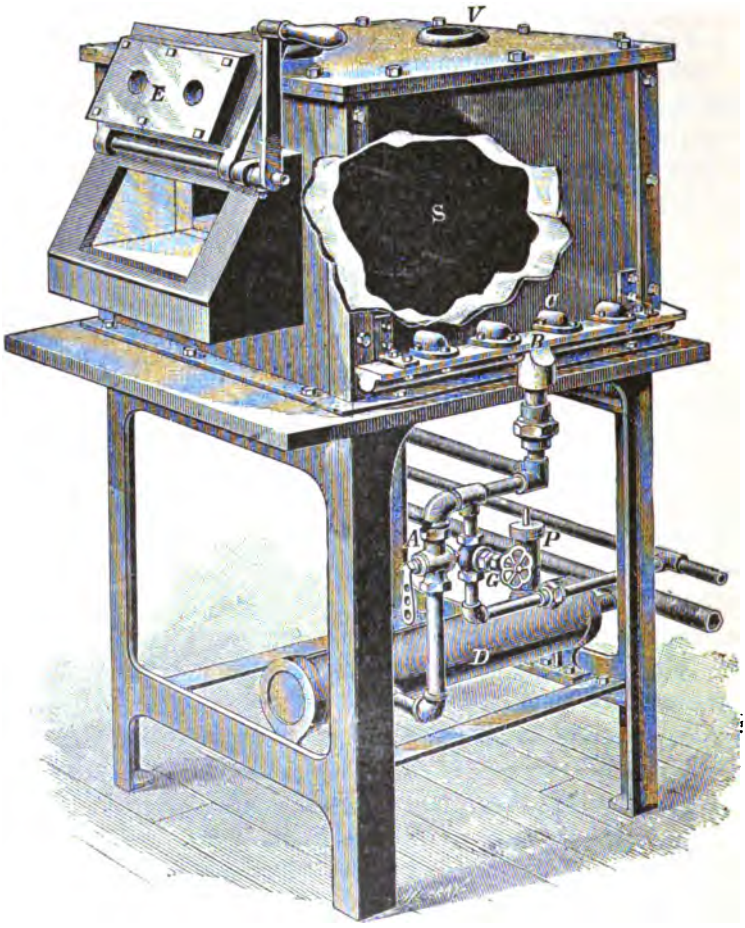
In a discussion of this paper by Henry M. Howe, Professor of Metallurgy, Columbia University, it was brought out later that, according to *Plattner* (Grillage, p. 259 et seq.), charcoal could not be expected to eliminate arsenic from arseniate of copper, but that ferric arseniate could be easily reduced thereby with expulsion of As_2O_3.

Professor Howe writes: "May it not be that, if an ore containing arsenide of iron, say arsenopyrite or an arsenical iron-copper matte had been used (by Mr. Pearce), part at least of the arseniate formed would have been arseniate of iron and that this would have been decomposed by the coal with expulsion of its arsenic?" Accordingly, it was at Professor Howe's suggestion that this work was undertaken, with the specific object of answering the above query—namely: Will we not get arsenic eliminated by charcoal, when we roast a material containing arsenides of iron instead of arsenides of copper?

Experimental Part.

The material used was a copper matte containing 50.16 % Cu, 16.82 ozs. Ag, 0.18 oz. Au, and practically no arsenic. To this was added arsenopyrite and the whole finely ground (80 mesh).

After a careful sampling, analysis of the material showed 4.56 % As. The roasting was carried out in an oven-gas-furnace (see illustration), the inside dimensions of which were 18″ x 24″. The



Oven Furnace used for Roasting the Ore. *C*, valve controlling gas supply. *D*, air reservoir. *P*, air relief valve. *A*, cock controlling air supply. *B*, row of burners —there is also a corresponding row on opposite side of furnace. *S*, fire-brick slab separating the combustion chamber below from the heating chamber above. *V*, vent leading to chimney.

plan followed was first to roast two lots of the material simultaneously and under exactly the same conditions to approximately a dead-roast (each lot weighed 3¾ Kilos and each was contained in a shallow iron tray 7″x 23″), then to stir into *one* lot 10 % by

weight of pulverized charcoal, and to continue roasting slowly till all the carbon was consumed. The two pans were sampled simultaneously every half hour. The method of sampling was somewhat crude, but perhaps the best possible under the circumstances, it was: first to thoroughly rabble the charge to be sampled, then to scoop up portions of the material in that pan from about ten different places, by means of a long iron spatula. All the portions so collected from a pan were then mixed to form a sample. The temperature of the pans was taken at intervals by means of a Le Chatelier Pyrometer. The whole roast took nearly seven hours to carry out—the charcoal being added to the *one* pan two hours before the roast ended.

Methods of Analysis.

The large samples, secured as above, were carefully resampled and portions of about five grams finely ground in an agate mortar. Portions of these latter, weighing about one gram, were then assayed for arsenic by the regular Pearce method, using the zinc-oxide modification and iron crucibles for the fusions. In other portions of from 2 to 3 grams, the soluble copper ($CuSO_4$) was determined by leaching with hot water and then titrating by the "cyanide method" (bulk of solution = 100 c.c., excess of ammonia, 0.96 specific gravity, was 3.5 c.c.). The analytical results so obtained have been assembled as follows:

Time.	Percentage of As.		Percentage of Cu in $CuSO_4$.	
	With C.	No C.	With C.	No C.
12.00 M.	4.562	4.562	0.00	—
12.30 P.M.	4.290	4.738	—	0.00
12.45	3.918	—	0.00	—
1.00	2.605	2.500	—	0.00
1.35	1.461	—	—	—
2.05	0.914	0.823	1.94	—
3.00	0.749	0.505	—	5.23
3.35	0.577	—	3.80	—
4.00	—	0.467	—	3.78
4.30	0.767	0.585	3.19	—
5.00	0.657	0.726	—	2.95
5.20	0.565	0.670	0.23	—
5.40	0.564	0.632	—	2.95
6.05	0.548	0.568	0.84	—
6.40	0.512	0.537	—	3.10

These values, for convenience of interpretation, have been plotted—see plate I.

OBSERVATIONS ON ROAST AND DISCUSSION OF RESULTS.

At 12 M. the two pans containing *identical* charges were put into the oven-furnace and the gas fired so as to give a very low red heat. White suffocating fumes (As, As_2O_3, As_2S_3, S, SO_2, etc.) appeared fifteen minutes after beginning the roast. These became increasingly dense during the next thirty minutes, then died away gradually, till after ninety minutes from the start (1:30 P. M.) they had quite disappeared. At 1:45 it was noted that the charges no longer glowed as brightly as before; on the contrary, they appeared nearly black, while the roasting seemed almost at a standstill, so that in order to facilitate the oxidation it was found necessary to supply more gas to the furnace. This meant that by about 2 P. M. most of the sulphur had been eliminated. Now, by reference to our table of plotted values, we note that the great bulk of the arsenic was likewise expelled during nearly the same period (12 M.–2 P. M.). Accordingly the great bulk of both the arsenic and the sulphur were eliminated simultaneously. This coincidence can be explained. Thus it is known, for example, that As_2S_3 is volatile and possibly *some* of the arsenic lost at this time was eliminated in direct combination with sulphur. The chances are, however, that *most* of the arsenic was oxidized to As_2O_3 and as such volatilized. The heat necessary for the formation of arsenious acid and its subsequent volatilization was supplied in this case almost entirely by the oxidation and elimination of sulphur as sulphurous acid (the heat given by the furnace being purposely kept at a minimum), so that loss of sulphur and loss of arsenic necessarily went hand in hand. Undoubtedly some non-volatile arsenic acid (As_2O_5) likewise tended to form at this time but, owing to the comparatively strong reducing conditions at hand, As_2O_5 was not permitted to accumulate. Thus, due to the excess of SO_2 present, of FeO, Cu_2O, etc., and of unaltered sulphide and arsenide—As_2O_5 was reduced as fast as formed to As_2O_3 and in this manner eliminated. (Plattner, p. 162.) So that while the reducing conditions were, comparatively speaking, so very strong, it is impossible that much metallic arseniate could have been formed, at least up to 1 P. M. From this time on, however, $CuSO_4$ accumulated in increasing amounts, we therefore judge by inference that the reducing conditions after 1 P. M. steadily weakened—less and less unaltered sulphide and arsenide remained to act as reducers, more and more FeO, etc., was oxidized to Fe_2O_3, etc., while at the same time the

atmosphere of the furnace was becoming poorer in SO_2, As_2O_3, etc., and so correspondingly richer in oxygen. In short after 1 P. M. oxidizing conditions were more and more getting the upper hand. On account of this increasing supply of oxygen from 1 P. M. to 2 P. M. two consequences followed:

First.—Arsenic acid was not, as before, instantly reduced but, permitted to remain intact, united with metallic oxides to form arseniates, themselves *more* or *less* stable towards reduction (vid. p. 67, Plattner's Statement).

Secondly.—SO_3 at this elevated temperature, by reductions of rich metallic oxides and by combination with oxygen of the air brought about by katalytic action, produced SO_3 in increasing proportions, so that from 1 P. M. to 2 P. M. the same conditions that favored the accumulation of As_2O_5 and of arseniates also favored the formation of SO_3 in excess. Of course much of this SO_3 at once combined with metallic oxides to form sulphates, thus at 1 P. M. we note that $CuSO_4$ was just beginning to accumulate. We believe, however, that much sulphate was formed in another way —viz.: through the decomposition of arseniates by SO_3 (Plattner, p. 160), according to the equation

$$RAs_2O_6 + SO_3 = RSO_4 + As_2O_5,$$

and perhaps much of the arsenic lost after 1 P. M. was eliminated in some such way as this. It is to be noted, however, that the action of the SO_3 is merely to release As_2O_5 from combination. In order that expulsion of arsenic may follow, this As_2O_5 must then be reduced to the volatile form, As_2O_3, by S, SO_2, FeO, etc. During this time of rapid removal of arsenic (1 P. M. to 2 P. M.) we are really sure that a quantity of S and of SO_2, etc., sufficient for this reduction of As_2O_5, was actually present, since the charge was self-roasting almost up to 2 P. M., which of itself indicates an excess of sulphur, and moreover SO_3 during the same period was present in excess, the formation of $CuSO_4$ dating from 1 P. M. Hence here are the two conditions (viz., an excess of SO_3 to decompose the arseniates and of S and SO_2 to act as reducers) that are theoretically necessary for the breaking up of metallic (Cu and Fe) arseniates (with elimination of As_2O_3). So that possibly this course of reasoning explains with a considerable degree of truth the rapid loss of arsenic observed between 1 P. M. and 2 P. M. and also, though perhaps to a less extent, the corresponding increase of

$CuSO_4$ (resulting from breaking up of arseniates by SO_3) that took place during the same period.

From 2 P. M. to the close it will be observed that the loss of arsenic was very gradual and very limited.

From 2 P. M. to 3 P. M. the quantity of $CuSO_4$ rapidly increased, indicating the presence of an excess of SO_3; during the same period however the loss of arsenic was insignificant when compared with that lost the previous hour. The reason for this probably is: that the conditions from 2 P. M. to 3 P. M. had now become scarcely at all reducing, thus the material at 2 P. M. had ceased to be self-roasting therefore not much sulphur was left at 2 P. M. to act as a reducer, so that even though metallic arseniates were decomposed by the existing SO_3, the non-volatile arsenic acid, thus liberated, had very little S or SO_2 to reduce it to a volatile form, but for the most part simply went back again into combination as metallic arseniate and consequently only a moderate loss of arsenic followed. In like manner can be explained why there was practically no removal of arsenic from 3 P. M. to 4.45 P. M.; $CuSO_4$ having ceased to form at 3 P. M. (indicating that all the S was in the oxidized condition), gradually decomposed at the existing temperature, so that after 3 o'clock SO_3 was supplied solely by the breaking up of sulphates according to the reaction:

$$CuSO_4 + \text{heat} = CuO + SO_3.$$

But this SO_3, no matter what the excess, was powerless to expel arsenic. since the reducing conditions, viz.: the presence of unoxidized S., etc., necessary to bring about the formation of the volatile oxide, As_2O_3, were now *entirely* wanting.

At 4:45 P. M. about 10% of powdered charcoal was stirred into one pan. Here you say we have supplied the necessary reducing condition so much insisted upon. Yes, but note the rapid destruction of $CuSO_4$ and of SO_3 that immediately followed,

$$2CuSO_4 + 2C = Cu_2O + 2SO_2 + CO_2 + CO.$$

In short, the reducing agent supplied was of such a nature that it quickly destroyed all our SO_3; this left only carbon to act and carbon by itself is only effective in expelling arsenic from easily reduced arseniates like arseniate of iron; at all events the figures show that the addition of charcoal brought about no marked elimination of arsenic. Accordingly our results lead us to con-

clude with Mr. Pearce that under the conditions named carbon is non-effective in expelling arsenic from roasted arsenical ores and mattes. This non-expulsion, we believe, resulted as indicated:

First.—Because the reducing agent employed, viz., *carbon*, rapidly destroyed all the SO_3 present, and neither carbon nor SO_3 is by itself effective in breaking up copper arseniate, or, in general, any other difficulty reduced arseniate. (Vid. p. 67, Plattner's statement.)

Secondly.—Because notwithstanding the fact that at the beginning our material contained solely arseniate of iron, nevertheless, at the end the arseniates present were chiefly of the copper-arseniate class, since they were non-reducible by carbon alone. (Vid. Plattner, p. 261.)

It was only natural, then, for the above two reasons that no marked expulsion of As_2O_3 resulted from the introduction of charcoal into the roasting mixture. Thus while at the beginning of the roast the arsenic was solely in combination with iron as arsenopyrite (FeAsS), nevertheless, at the end it appears to have been chiefly in combination with copper, as arseniate of copper. Why is it, then, that arseniate of copper was formed during the roast rather than arseniate of iron? Simply, we believe, because the copper compound is the more stable, this being evidenced by the fact that it is reduced with greater difficulty and that it withstands better high temperatures. The result is that arseniate of copper was the one formed, in accordance with the general chemical principle that the most stable compound that *can* form under any given conditions is the one that actually does form.

Therefore it may be true that, given a material containing Fe, Cu, As and S, no matter *what* the original combination of the arsenic—the resulting arseniate produced by roasting will be mainly arseniate of copper. Mr. Pearce used enargite (Cu_3AsS_4), we have used arsenopyrite (FeAsS). In both cases carbon proved non-effective in expelling arsenic, for the reason, we believe, that in both cases the chief end-product was the non-reducible arseniate of copper.

ADDENDA.

1. It will be seen that this explanation follows theoretically from Plattner's statement about the non-expulsion of arsenic from arseniate of copper; it would be of considerable value to test this statement practically by preparing "what-are-known-to-be" pure

arseniate of copper and pure arseniate of iron,—then add each in certain proportion to a copper ore or matte, roast in separate pans under identical conditions, add to both fine coal, then sample and determine the percentage expulsion of arsenic in each. Arsenic should be eliminated according to Plattner from the lot containing arseniate of iron and not from the other.

2. After the addition of charcoal to the one pan at 4.45 P. M., it will be noted that the percentage of arsenic in pan No. 2 apparently increased, which is very improbable, so that this and similar discrepancies are to be laid to unavoidable errors chiefly due to sampling. This means that in our diagram of plotted values too much cannot be inferred from the minute formation of curves, it is only their general contour that can be profitably discussed.

3. TABLE OF TEMPERATUARES RECORDED.

1.00 P. M.	470°C.	450°C.
1.20	690	530
2.30	525	495
2.45	510	490
3.00	510	520
3.50	610	600
4.30	——	600
4.45	charcoal added	——
5.10	560	475
5.50	635	630
6.15	655	660
6.40	770	765

AUTHORITIES CONSULTED.

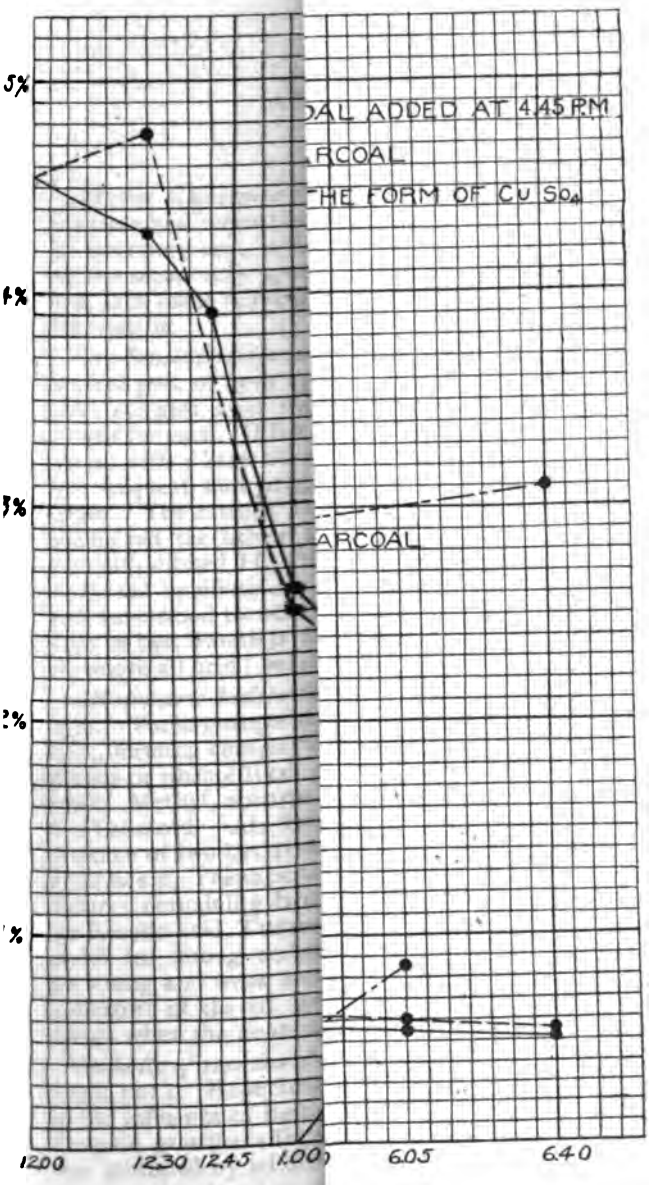
1860.—" Traitè Theorique des Procèdes Metallurgique de Grillage." Translated from the German of Carl-Friedrich Plattner, by Fetis. Paris et Liège. (P. 259 et seq.)

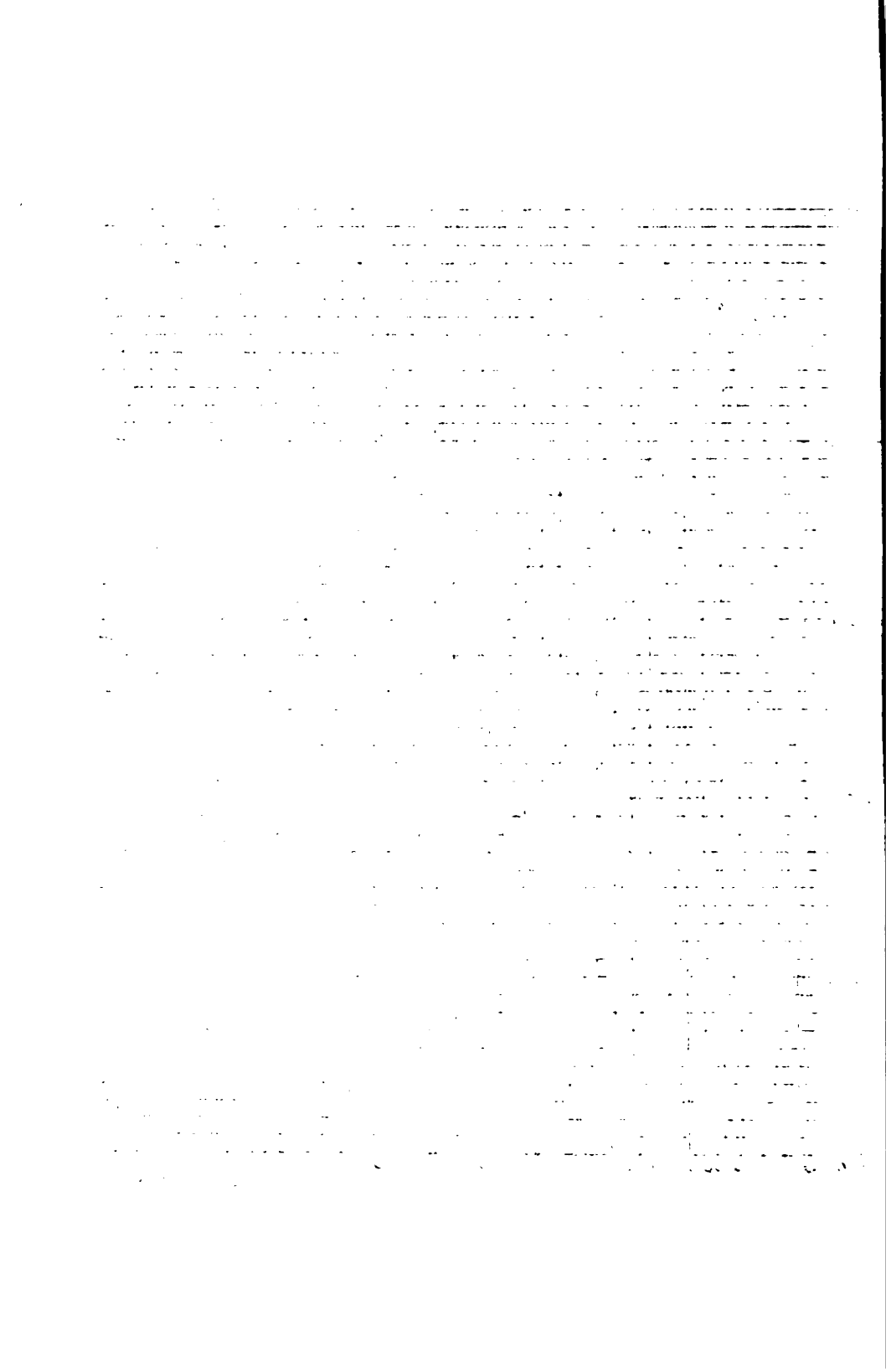
1882.—" Compendium der Metallurgischen Chemie," by Carl A. M. Balling.

1885.—Bull. No. 26—U. S. G. S. (p. 25). " Copper Smelting," by Henry M. Howe.

1889.—T. A. I. M. E., Vol. XVIII., 1889-90, " Progress of Metallurgical Science in the West," by Richard Pearce. Pp. 62, 63 and 457.

PLATE I.


OAL ADDED AT 4.45 P.M.
RCOAL
THE FORM OF Cu So4
ARCOAL
12.00
12.30
12.45
1.00
6.05
6.40



ABSTRACTS.

ANALYTICAL CHEMISTRY.

BY ELWYN WALLER.

Alkaline Glassware. Liebermann (*Ber.*, XXXI., 1818) gives warning that there has recently appeared in the market, a fine looking glassware for laboratory use, which has no tendency to crack and in many other respects seems very good, but gives up so much alkali to solutions boiled in it, as to cause serious errors unless one has taken the precaution to test and reject it.

Very Sensitive Litmus Paper. Wobbe (*Apoth. Ztg.*, XX., 126). One hundred gms. of best quality of litmus are extracted successively with 500 gms., 250 gms. and 250 gms. of alcohol in a flask with return cooler, half an hour for each. The alcoholic extracts are put aside, and the residue extracted with 1 liter of water, with which it is kept in contact for 24 hours with frequent shaking, the flask being closed with a plug of absorbent cotton. The extract is then filtered, and the filtrate divided in halves—one for red the other for the blue paper. That for red is rendered just acid with diluted H_3PO_4; that for blue is halved, and one half rendered barely red by dilute H_3PO_4 when it is mixed with the other half. After both have stood to settle for one day these are filtered and absorbed by strips of best Swedish filter paper (which have been previously extracted to remove all acid) which are then dried.

Alkalimetric Indicators. Glaser (*Fres. zts. Anal. Chem.*, XXXVIII., 273). Three groups are recognized: 1st, substances positively acid or basic, forming comparatively stable salts. These are diazo or triazo compounds or phenol-like substances with several hydroxyls. In this group come: Methyl orange, Tropæolin oo, Congo red, Cochineal, Iodeosin and Lakmoid. 2d, Indicators whose acid character is induced by the presence of two hydroxyl groups. Salts not very stable. Here belong: Fluorescein, Phenacetolin, Hæmatoxylin, Gallein and litmus. 3d, Indicators containing but one hydroxyl group. Salts very unstable. Such are Rosolic acid, Turmeric, Phenolphthalein and Flavescin. First group useful for strong acids. 2d for strong and medium strong acids. 3d for strong and weak acids. The degree of dilution is important. With indicators of the 3d group in dilute solutions the change of color only occurs when the neutralization point is passed, etc.

Stability of standard oxalic acid solution. Jorissen (*Zts. Angew. Chem.*, 1899, 521). Experiments showed that the deterioration was mainly due to the influence of light, which affected even moderately strong solutions. Fungoid growths affected weak solutions even in the dark, which effect was inhibited by addition of H_2SO_4 or H_3BO_3. Presence of $MnSO_4$ aided in deterioration and loss of acid strength whether in light or darkness.

Separations by HCl gas. Moyer (*J. Am. Chem. Soc.*, XVI., 642).

The separations of certain metals when mixed in the form of sulphides, by heating in a current of dry HCl gas, was tried with fairly good success in the following cases: Separation of Pb from As, from Sb, and from Bi, Cd from As, and Ag from As.

The separation of metals when as sulphides as well as in the form of oxides, seems therefore to be quite possible.

Volumetric for Nickel. Giorgis (*Gaz. Chim. Ital.*, XXIX., 2). The Ni is precipitated by use of $H_2C_2O_4$ solution of BaC_2O_4 or SrC_2O_4 containing a known amount of RC_2O_4. The Ni may be estimated indirectly by titration of the filtrate (or an aliquot portion thereof) by standard $K_2Mn_2O_8$, or more directly by decomposing the precipitate with Na_2CO_3—acidifying with H_2SO_4 and titrating with $K_2Mn_2O_8$.

Nickel in Steel-Colorimetric. Lucas (*Bull. Soc. Chim.* [3], XXI., No. 9). The method depends on the red coloration produced by ammonium or potassium sulpho-carbonate. The reagents are prepared as follows: $(NH_4)_2CS_3$. Digest freshly prepared $(NH_4)_2S$ solution for 24 hours at a gentle heat, with one-twentieth part of its weight of CS_2. Then decant from the CS_2 remaining; K_2CS_3 is prepared in essentially the same manner using freshly prepared K_2S, and digesting with one-twenty-fifth its weight of CS_2. Dilute both until they have the same depth of tint.

A standard solution of $Ni(NO_3)_2$ is made from which a portion is taken for each test and solution of NH_4 salts added so that when used for comparison it contains in the proportion of 0.1 gm. Ni per liter.

Dissolve 1 gm. of nickel steel in aqua regia, precipitate the Fe twice successively by NH_4OH with some NH_4 salt. Dilute to 500 cc and take lots of 50 cc. for the test. To one lot add 10 cc. of the $(NH_4)_2CS_3$ solution, to another the same amount of K_2CS_3 solution. If the first lot shows a deeper color than the second Co is present which must be separated from the Ni. If not—and also if Cu is absent—comparison may be made with known portions of the standard, diluted as may be indicated by trial.

The coloration is produced in neutral or alkaline solution, but in the latter case, especially when exposed to air, it fades rapidly. Hence the use of solutions as neutral as may be, and exclusion of the air (by corking up, are advised.

Electrolytic Separation of Cadmium from Iron. Stortenbecker (*Zts. f. Electrochem.* IV., 409). The iron should be in the ferrous condition—brought to that state if necessary by use of Na_2SO_3. The mixture of the salts of the two metals (in 100 cc.) slightly acid with H_2SO_4, should receive the addition of about 2 to 3 gms. of KCy, and be heated until clear. The addition of a little KOH will hasten the clearing should it prove slow. The Fe is then in the form of double cyanide not decomposable by the electric current. Dilute to 200–250 cc. and electrolyze with a current of 0.10 ampère per sp. decimeter.

Oxygen in Copper. Lucas (*Bull. Soc. Chim.* [3], XIX., Nos. 16–17). A modification of Hampe's method is recommended. The $AgNO_3$ was prepared by crystallizing and recrystallizing until the mother liquors were no longer acid. The crystals (protected from light) were dried over CaO. A 5 per cent. solution of these was then made, and after standing, decanted into a red glass flask. The Cu was rolled in strips about 0.15 mm. in thickness, cleaned with glass paper, and then treated (2 gms. of Cu to

120 cc. of the $AgNO_3$ solution) for 15 hours in vacuo (without shaking). The residue was filtered through asbestos and washed until no more Cu was dissolved out, and again treated for 2 hours in vacuo, and tests made in the solution for the presence of Cu. After this, dissolved in HNO_3. Ag separated by HCl, and the Cu determined by electrolysis, its weight being multiplied by 1.689 to get Cu_2O. Tests must be made to make sure that it contains no Ag.

Action of Stannous Chloride on Lead Salts. Vannio and Treubert (*Berichte*, XXXI., 1118). In alkaline solution all Pb was precipitated in metallic form. To solution of the Pb salt was added $SnCl_2$ solution, and then a large excess of 10 per cent. NaOH. By heating slowly up to boiling the reduction occurred. The precipitate was washed by decantation with dilute H_2SO_4 (5 per cent.), then with boiled water, finally with absolute alcohol and dried at 105° C.

Determination of Bismuth. Vannio and Treubert (*Ber.*, XXXI., 1303). The weakly acid solution of Bi is warmed with addition of formaldehyd solution and a decided excess of NaOH (10 per cent. solution). After standing on the water bath, with stirring, it is heated for a few minutes over a naked flame, with renewed addition of formaldehyde and alkali. Wash by decantation with water, press the precipitate into masses by use of the rod, and finally transfer to a weighted filter (Gooch or other), wash with absolute alcohol; dry at 105° C. and weigh.

Pearce's Method for Arsenic modified. Bennett (*J. Am. Chem. Soc.*, XXI., 431). The method fusing with alkaline nitrate and carbonate, dissolving, boiling down, etc., and precipitating Ag_3AsO_4 in *absolutely* neutral solution, after washing dissolving the precipitate in HNO_3, and titrating Ag by NH_4CNS solution, has a critical point—the exact neutralization of the solution for precipitation of the Ag_3AsO_4. The author deems that he gets results more conveniently by acidifying the solution of the melt with $HC_2H_3O_2$, boiling out nitrous fumes, etc., and then by use of phenolphthalein as a guide neutralizing with NaOH, bringing eventually the state of the solution to a point where but one or two drops of the acid have decolorized the phenolphthalein.

Precipitation with $AgNO_3$, etc., are then conducted as usual.

Analysis of Stibnite. Kitzing (*Zts. off Chem.*, 1898, 830). 0.5 gm. is weighed out, mixed with $H_2C_4H_4O_6$ and HNO_3 added cautiously, at first dilute, afterward conc. It is then allowed to stand for 24 hours, some Br is added and after standing if any S is visible, a few crystals of I are added. By careful evaporation on the water bath, adding water and repeating, all HNO_3 and Br are driven off, when it is taken up with HCl, and SO_3 precipitated in the usual manner with $BaCl_2$. For Sb, the method of solution is the same. The Sb is precipitated by H_2S, filtered and dried, being oxidized in a weighed crucible by vapors of fuming HNO_3 finished by adding HNO_3 and vaporizing off, and weighed as Sb_2O_4.

Separation of Cerite Metals. Muthmann and Rollig (*Ber.*, XXXI., 1718). The mixture of oxides was calcined in a Hessian crucible until the color was chocolate brown and the Ce was in the higher form of oxidation. The oxides were then digested with conc. HNO_3 which dissolved all but the Ce, left behind as basic nitrate. This insoluble portion treated with NH_4NO_3 gave the $CeNH_4$ compound, which could be crys-

tallized pure from the acid solution, provided the concentration were not carried too far, in which case a little of the La compound would separate also.

In the HNO_3 solution the last portions of Ce were separated out by nearly neutralizing, adding an excess of ZnO, and then pouring in concentrated solution of $K_2Mn_2O_8$ until the pink color held after stirring and standing. The precipitate consists of MnO_2 and $Ce(OH)_4$.

The solution was tested for Ce by H_2O_2 test.

When free from Ce, it was acidified with $HC_2H_3O_2$ and Zn separated by H_2S. The oxides were then precipitated by $H_2C_2O_4$, and the oxalates ignited and dissolved in HNO_3. The neutral solution of the nitrates was then boiled, and pulverized K_2SO_4 gradually added until a portion of the solution when cooled and filtered gave no spectrum of Di. La and Di were thus separated as double sulphates, Yt remaining in solution. To make the separation complete, the operation had to be repeated. To convert from sulphates to oxalates the sulphates were digested hot for some time with conc. $H_2C_2O_4$ solution, steam being passed in at the same time. The oxalates were converted to nitrates as before.

To separate La and Di Welsbach's method of dissolving one-half in HNO_3 and digesting the other half with this solution to get basic nitrates of which the La salt dissolves and the Nd and Pd salts do not, was found to be effective, but a much more convenient way was found in precipitation with calcined MgO. By adding the MgO little by little to the boiling solution, a point is reached when Di has been precipitated, and La remains in the solution. Spectroscope test must be made to determine when this point is reached. Further addition of MgO will then precipitate La.

Filter and precipitate La by addition of NH, Cl and $(NH_4)_2C_2O_4$.

Electrolytic separation of the Halogens. Spekeler (*Zts. f. Elektrochem.* V., 539). The electromotive forces necessary for this decomposition of halogen acids are: HCl 1.31 volts, HBr 0.94 volt, HI 0.52 volt. By use of a thermopile of constant electromotive force, and a resistance bar rendering it possible to regulate the current very accurately the separation can be accomplished, using a platinum cathode and a pure silver anode. A current of hydrogen must be continuously passed through the solution to keep air or oxygen from the cathode. A sensitive galvanometer in the circuit will show the exact moment when the halogen for which one is working has been eliminated. The cathode is then withdrawn, washed, dried at 120° and weighed.

Iodine in Presence of Bromine. Imbert and Compan (*Bull. Soc. Chim.* [3], XXI., No. 6). Addition of H_2SO_4 with CrO_3 *in the cold* to mixtures of bromide and iodine, caused liberation of I only, which could be titrated by standard $Na_2S_2O_3$.

Selenious Acid Titration. Norton (*Am. J. Sci.* [4], VII., Apr., '99). Norris and Fay have described (*Am. Chem. Jour.*, XVIII., 703) a method for titration of SeO_2 by adding N/10 $Na_2S_2O_3$ in presence of free HCl and titrating back with N/10 I.

The author finds that for accuracy not more than 20 cc. of N/10 $Na_2S_2O_3$ should be present in excess over the amount necessary to reduce the SeO_2 present. If the solution is diluted to 400 cc. not over 10 cc.

of HCl (Sp. Gr. 1.12) should be present in excess, or the volume may be 200 cc. with 5 cc. HCl of this strength. Departure from these conditions will give erroneous results.

Phosphine in Acetylene. Hempel and Kahl (*Zts. f. Angew. Chem.*, 1898, 53). To determine PH_3 in acetylene, measure in a gas burette filled with Hg and thence transfer to another burette filled with Hg and 3 cc. of $CuSO_4$ solution in H_2SO_4 and saturated with C_2H_2. Shake 3 minutes and then measure the gas. One quarter of the gas volume absorbed represents PH_3 present.

Decomposition of Silicates by Boric Acid. Jannasch and Weber (*Ber.*, XXXIII., 1670). The method already described (vid QUARTERLY, XVIII., 54) was at best only partially effective with disthene and several other minerals containing aluminum silicates. Further experiments have shown that by use of higher temperatures (obtained by use of a blast lamp fed with oxygen and illuminating gas) such minerals when mixed in finely pulverized condition with B_2O_3 could be satisfactorily decomposed. 0.5 gm. of disthene with 1.5 gms. of B_2O_3 was thus successfully decomposed. Topaz was managed with more difficulty. Only 0.1 to 0.2 gm. of the finely pulverized mineral could be managed at one fusion.

Carbon Combustion in Platinum Crucible. Shinier (*Jour. Chem. Soc.*, XXI., 557). The proposition is "to use a Pt crucible with a water cooled stopper in place of the combustion tube, an ordinary small blast lamp and Bunsen burner in place of the combustion furnace, and air instead of oxygen." The Pt crucible has fitted to the outside a ring of sheet copper brazed together, to stiffen the upper rim. The stopper is a round box of thin sheet copper brazed together, made to fit the crucible loosely enough to allow surrounding it with a band of thin rubber which makes a tight joint between it and the crucible. Tubes for inlet and outlet of water pass through the top of the box, and tubes for inlet and outlet of air to the cavity of the crucible, pass completely through. The stopper should not flare more than the top of the crucible or it may be forced out by pressure within. In use the top of the crucible is surrounded by two or three turns of lampwick which dips into the trough receiving the overflow of water. The carbon is filtered on an asbestos bed in an ordinary glass funnel, and after washing and drying the whole is placed in the crucible *carbon side down*, the stopper adjusted, etc., and the heat of a blast lamp applied, the air being supplied from a pair of aspirator jars, suitably connected. Next to the crucible in the train is placed a small diameter brass tube 10 to 12 inches long filled with CuO. Next, a glass tube filled with wet glass beads kept cool by wet wicking. Next, a large $CaCl_2$ tube. Next the KOH Geissler bulbs, and finally a guard tube of $CaCl_2$. Other uses of the crucible are suggested.

Volumetric for Carbon. Imbert and Compau (*Bull. Soc. Chim.* [3], XXI., No. 6). The process depends upon the oxidation of the C by use of CrO_3 (in known amount) in presence of H_2SO_4, evaporating the solution until it is sufficiently concentrated to allow the reaction to take place. Disregarding the H_2SO_4 the reaction is:

$$3C + 4CrO_3 = 2Cr_2O_3 + 3CO_2.$$

The solution is then diluted and KI added with more H_2SO_4 (4 per cent.) if necessary. The excess of CrO_3 sets free the I which may be

titrated with standard $Na_2S_2O_3$. The authors prefer to remove the I from the solution by shaking with CS_2 in a stopcock bulb, shaking the CS_2 solution with $NaHCO_3$ solution and then titrating until the violet color has been entirely removed.

Carbon, Volumetric. (*C. N.*, LXXX., 52.) The method proposed is not entirely novel. It consists in oxidizing by use of a known amount of CrO_3 with H_2SO_4, and titrating the excess of CrO_3 remaining. The CrO_3 solution is best made $\frac{4}{10}$ N ($K_2Cr_2O_7$) and containing 500 to 600 cc. conc. H_2SO_4 per liter. 25 cc. of this solution will oxidize 1 per cent Cu in 130 grms. of steel. The C should be separated from the steel by the usual method of Cu solutions, filtered on asbestos, and very thoroughly washed free from $FeCl_2$ and Cu_2Cl_2 until the washings no longer discharge a faint $K_2Mn_2O_8$ coloration. The asbestos carrying the C etc., is placed in a beaker, a suitable amount of the $K_2Cr_2O_7$ solution added and the beaker stood in a boiling water bath. The operation is finished when the asbestos is no longer made to float on the surface by the entangled CO_2 and stirring gently causes no more bubbles to appear. The solution may then be titrated with standard ferrous solution. Graphitic carbon is but slowly oxidized by this means at the temperature of a water bath. By using a $CaCl_2$ bath and keeping the temperature at 130° C. the oxidation may be effected in about 1½ hours. In an ordinary steel the C is oxidized in about 20 minutes. In special steels, *e. g.*, tungsten steel, the N remains with the C and unless special treatment is applied close results cannot be obtained. Mo does not interfere. Cr, except when present as more than a trace, invalidates the method.

Carbon monoxide estimation. Schlagdenhauffen and Pagel (*J. Pharm. et de Chim.* [5], IX., No. 4). Passing CO over Ag_2O in a U-tube, and then into $Ba(OH)_2$ solution, showed the formation of CO_2. The reaction was found to be quantitative when the U-tube was heated to 54° to 60° C.

$$Ag_2O + CO = CO_2 + Ag_2,$$

With Cu_2O dried at 150° a similar reaction occurred, when the U-tube was heated to 215° to 300°. With these oxides a quantitative estimation of CO is possible, the products of the reaction being passed into potash bulbs. Of course guard bulbs containing $Ba(OH)_2$, or some alkaline solution must be placed in the train before the gas reaches Ag_2O or Cu_2O.

Experiments were made with other oxides. Bi_2O_3 affords BiO, reaction occurs at 385° to 400°. Pb_3O_4 affords Pb and PbO, reaction begins at 225°. PbO affords Pb, no reaction below 300°. $Pb(OH)_2$, reaction at 430° not sharply defined.

Carbonate in Soils. Stutzer and Hartlieb (*Zts. Angew. Chem.*, 1899, 448). The determination of $CaCO_3$ in a soil is of considerable importance. To determine total CaO, or total CO_2 does not serve the purpose. The object aimed at was accomplished by adding to a weighed quantity of the soil an equal weight of NH_4Cl in solution, and distilling off NH_3, coming over presumably as $(NH_4)_2CO_3$, and titrating. $FeCO_3$ caused no interference if the weighed amount of soil was boiled for a short time with water before adding the NH_4Cl.

Calcium carbonate in Soil and Marls. Mayer (*Laudw. Vers. Stat.*,

LI., 339). In some cases determination of CO_2 by loss give satisfactory results. When $FeCO_3$ is present, it is necessary to use $HC_2H_3O_2$ (diluted with two parts of water) instead of HCl in the Scheibler apparatus. Under those conditions $FeCO_3$ is not attacked, and the CO_2 obtained is only that from the $CaCO_3$ present.

Estimation of Formic-aldehyde. Blank and Finkenbeiner (*Ber.*, XXXII., 2979). The method consists in oxidizing to formic acid by H_2O_2 and titration.

Three gms. of the formic-aldehyde solution is placed in a conical flask with 25 cc. double normal NaOH solution; 50 cc. of H_2O_2 solution (2 to 3 per cent. strength), is then added gradually (if the H_2O_2 contains free acid, this must be determined and allowed for in the calculation). With strong solutions two or three minutes suffice for the reaction, with weaker solutions of formaldehyde, ten minutes or more may be necessary. The solution then is titrated back with standard acid solution. Litmus is used as the indicator.

Boric acid test. Lénher and Wells (*Jour. Chem. Soc.*, XXI., 418). The mode of applying the test is modified by mixing the substance to be tested in a test tube with H_2SO_4 and alcohol, and closing the mouth of the tube with a cork carrying a bit of tubing drawn out to a jet. Then on heating the test tube, and directing the stream of issuing vapor at a Bunsen flame the green tinge is easily observed. A comparison of the relative sensitiveness of different tests for B_2O_3 is given. The ordinary flame test and the KF and $KHSO_4$ method would detect 0.01 gm. The flame test modified as above and the (Iles) glycerine test detected 0.001 gm., while the tumeric paper test was most sensitive of all. (0.0001 gm.)

Volumetric for Boric acid. Jones (*Am. J. Sci.* [4], VII., Feb., '99). A mixture of B_2O_3 and mannite solutions affords a compound having acid properties akin to but a little stronger than citric acid. A mixture of KI with KIO_3 is but slowly affected by this compound, though mineral and other strong acids at once set I free. The free I may be removed by $Na_2S_2O_3$, leaving the B_2O_3 free, to be titrated with phenolphthalein indicator.

For the process add to the solution HCl until it is decidedly acid to litmus, then 5 cc. of $BaCl_2$ (to prevent possible interference of CO_2 later on). Then mix in a separate breaker 10 cc. of a 25 per cent. solution of KI and 10 cc. of saturated solution of KIO_3. This amount should be sufficient to react completely with the free HCl added, and leave an excess besides. The mixture of the solutions of salts may give free I and give blue with the few drops of starch solution which must be added. Neutralize this by careful addition of $Na_2S_2O_3$ solution. Test then first with a drop or two of the solution containing the B_2O_3. If the HCl is in too great excess, partially neutralize with NaOH. If insufficient no blue color will be shown, and all the B_2O_3 has not been rendered free. If the coloration shows right, mix the two solutions, and destroy free I by addition of $Na_2S_2O_3$ solution. Now add a few drops of phenolphthalein and run in standard alkali from the burette, until the color is strongly alkaline. Add now a pinch of mannite which should bleach out the alkaline color, and run in alkali again until a faint alkaline color is developed, which should be the end point, and addition of more mannite should fail to bleach it. If not titrate until addition of mannite fails to

remove the alkaline tint. About 1 to 2 gms. of mannite are necessary; the operation should be conducted in the cold, in about 50 cc. of liquid.

The end reaction occurs when $NaBO_2$ has formed, on which basis the calculation is made.

By this method, accurate results are quickly obtained.

Fl, SiO_2 and CO_2 if present do not affect the accuracy.

Distinguishing Ozone from hydrogen peroxide, or nitrous acid. Erlwein and Weyl (*Ber.*, XXXI., 3158). An *alkaline* solution of metaphenylmediamin hydrochloride, is colored yellowish brown by ozone, but not by nitrous acid (which gives the coloration in acid solution) or by peroxide. The oxygen of the air will, after a long time, produce this effect. 25 cc. of a solution containing 0.1 to 0.2 gm. metaphenyldiamine hydrochloride in 90 cc. of water, to which 10 cc. of a 5 per cent. NaOH solution has been added will give a decided reaction with 0.08 mgn. of ozone in the course of five seconds. The reagent should be freshly prepared.

Analysis of Dynamite, etc. F. W. Smith (*J. Am. Chemc. Soc.*, XXI., 425). For a dynamite containing nitroglycerine, sodium nitrate, wood pulp and basic magnesium carbonate or Kieselguhr, the author adopts this method:

10 gms. are weighed out on a pair of watch glasses and exposed in a dessicator over conc. H_2SO_4 for 5 days, loss is *moisture.*

10 gms. are weighed out and extracted with ether. If the dynamite contains only nitroglycerine and kieselguhr, the material should be treated in a beaker with the ether, and eventually poured into a (weighed) Gooch filter. In most other cases it suffices to weigh directly in the Gooch filter, and extract by percolation of the ether. Dry 2 or three hours at 80°C., loss is *moisture and nitroglycerine.*

Extract with water—displace water by acetone and dry. *Loss is* $NaNO_3$: KNO_3 is rarely used.

Ignite until white ashes remain. Loss is *wood pulp, bran, etc.* Methods for the separation of these are unsatisfactory. Their general character may be determined by testing with iodine, etc. If no earthy absorbents have been used, the ash is not likely over 0.1 per cent. If materially larger, treat the ash with dilute HCl, dry and weigh. Twice the loss by HCl is reckoned as *basic magnesium carbonate.* As that compound loses half its weight on ignition, the other half of the basic Mg carbonate is deducted from what is otherwise counted as wood pulp, *e. g.*, in a case cited: Loss on ignition 10.40 per cent., loss by HCl 0.90 per cent. Reported:

Wood pulp	10.40 less 0.9 =	9.50 per cent
Basic Mg Carb.	2 × 0.9 =	1.80 " "

The Lunge nitrometer may be used to check the results. Weigh out 0.5 gm. and pour over it 10 cc. conc. H_2SO_4; let stand 12 to 18 hours, when usually all has dissolved. Then run into the nitrometer, and conduct the operation as usual. Assuming $NaNO_3$ to be 97 per cent. pure one may calculate whether the loss by ether was nitroglycerine and that by water $NaNO_3$.

Gelatine Dynamite. Weigh out for moisture as before.

Weigh out about 15 gms. in an extraction thimble, and extract with chloroform in a Soxhlet. If the material melts together take it out and

break it up in a beaker with cold $CHCl_3$ until nitroglycerine is dissolved out. Loss in *nitroglycerine, sulphur and resin.*

Treat with cold water—loss is $NaNO_3$. Treat with acetone—loss = gun cotton; the residue, consisting of wood pulp, etc., is treated as previously described.

The chloroform of the first solution is evaporated off, and the residue treated with glacial acetic acid. The precipitated sulphur is filtered through a weighed Gooch crucible, resin washed off by strong alcohol, and sulphur weighed. Nitroglycerine is determined by extraction of a separate portion with ether, allowing the ether to evaporate spontaneously, and weighing. Some of the nitroglycerine is always lost by evaporation however. This may be rinsed into the nitrometer with acetic acid and tested there. Too much acetic retards the reaction, too little allows it to become dangerously violent.

Explosions. Lunge (*Zts. Angew. Chem.*, 1899, 537) records two cases. In the first mentioned a teacher had prepared oxygen in the ordinary way from $KClO_3$, and collected the gas in a glass gasometer, which at the start was full of water. When the illustration of the re-ignition of a glowing splinter was attempted, the gasometer exploded, injuring pupils and teacher with the fragments of broken glass. It was found that the water used in the apparatus had been used in a similar manner in collecting acetylene gas, and had dissolved enough to cause the accident.

The other case was inexplicable. A crystallizing tank in a $KClO_3$ factory took fire, and the fire was communicated to an adjacent tank. In the course of about ten minutes a store of 156 tons $KClO_3$, separated from these tanks by a brick wall, exploded so violently as to wreck not only the factory itself, but also a sulphuric acid plant (10 chambers) 150 meters distant.

Removing Lime and Magnesia from Waters. Griffin (*J. Am. Chem. Soc.*, XXI., 665). Experiments were made with various reagents which are used or have been patented for the purpose. Those used were NaOH, Na_2HPO_4, NaF, $Na_2Al_2O_4$, and $Ba(OH)_2$.

In experiments with solutions made up for the preliminary tests: in a solution of CaO, NaF proved to be the best; with $MgSO_4$, substances giving hydroxides (including $Na_2Al_2O_4$) proved most efficient. With $MgCl_2$ the aluminate worked the best.

In experiments with several different natural waters, NaOH was, on the whole, the most efficient, NaF seemed the best where $CaSO_4$ and $CaCl_2$ were the chief hardening ingredients.

Waters containing 0.020 to 0.025 gm. CaO per liter or 0.005 to 0.007 of MgO could not be appreciably improved by use of these reagents.

Victorium. A New Element. Crookes (*Chem. News*, LXXX., 49). The element is associated with yttrium, and was separated after fractionation by fusion of nitrates, then fractioning by crystallization of the oxalates, then fractioning by precipitation with K_2SO_4; symbol Vc. The atomic weight was found to be "apparently not far from 117," assuming that the oxide obtained was Vc_2O_3. This was of pale brown color easily soluble in acids. From hot HNO_3 solution the oxalate precipitates before Yt and after Tb. Its double potassium sulphate is less soluble than the corresponding Yt salt, and more so than those of the Tb and Ce groups.

ALUMNI AND UNIVERSITY NEWS.

SUMMER SCHOOL OF MINING.

The Summer School of Mining, of 1899, was held in the lead mining district of southeastern Missouri, and in the Wyoming Valley coal field, near Wilkes-Barre, Pennsylvania.

On May 29th the class assembled at Flat River, St. François County, Mo., where headquarters were established. This town, about sixty miles south of St. Louis, is situated in a flourishing lead producing region. The work was begun on May 29th, at the mine of the Central Lead Company, about one mile from Flat River. An invitation to visit this property had been very cordially extended by the officers of the Company, Messrs. Arthur Thacher, President (class of '77, S. of M.); J. T. Monell, Superintendent, and Robert K. Painter, Assistant Superintendent (class of '96, S. of M.), to each of whom our hearty thanks are due for the liberal manner in which all possible assistance and facilities were extended.

The class consisted of twelve students, eleven of the fourth year, and one, a graduate of Stevens Institute, who attended the Summer School preparatory to entering the third year for the degree of Engineer of Mines. By special arrangement the students named below (graduates of other institutions) made independent trips in the West during the summer, for studying mining, and on presentation of their note-books they will be credited with the work done, as though they had attended the regular Summer School session. Christopher Henne, 2d, devoted fifteen weeks to study in all the principal mining camps of Colorado, and at many mines and metallurgical works in Utah, Montana, Nevada and California He visited forty-one mines, sixty-one surface plants, twenty-five mills, eleven chemical extraction plants (for gold, etc.), nine smelters and two power plants. O. B. Perry spent nearly five weeks in Arkansas and Indiana. He made previously a seven weeks' trip among the copper and iron mines of Michigan and Alabama. E. Bamberger devoted six weeks to study several mines in Utah in the Tintic district. B. E. Russell was engaged on the Engineer's Staff of the Lehigh Valley Coal Company throughout the summer, utilizing his spare time in studying mining methods. M. Schwerin made a five weeks' trip in Idaho and Wyoming. He has already held a position with the De Beers Consolidated Mines, South Africa. Including these students, the total number engaged in summer work was seventeen.

Adjunct Professor Peele, in charge of the class, as usual, was assisted by Messrs. Wm. S. Thyng and Charles Fulton, graduates respectively of the classes of 1896 and 1897. It was intended to devote three weeks to the mine survey and to detailed study of the Central Mine and works, one week to the neighboring Theodora Mine, which is under the same management, and a fifth week to one or two other mines in the vicinity, together with the large concentrating mill of the St. Joseph Lead Company, a few miles north of Flat River. Arrangements were made also to visit the smelter of the last-named company, if time permitted.

Suddenly, however, on June 10th, when the class had barely completed two weeks' work, a number of cases of small-pox came to light in the town and vicinity, and an immediate change of base was made. This step seemed imperative, not only to avoid subjecting the students to quarantine of uncertain duration, but also to remove them from further danger of infection. A quarantine at Flat River was expected almost hourly, and was actually declared just after the class left town. On reaching St. Louis the case was laid fully before the State Board of Health, and under their advice (after a little fumigation) it was considered safe to resume the class-work elsewhere.

New arrangements were made by Professor Peele, at Wilkes-Barre, Pa., as expeditiously as possible, and the remainder of the session was devoted to studying the surface and underground work of a number of large collieries in the vicinity of that city. The following properties were visited: the Dorrance, Prospect, Maltby, Exeter, Stanton, Nottingham and Sugar Notch collieries, of the Lehigh Valley and the Lehigh and Wilkes-Barre Coal Companies, and the Glen Lyon and Nanticoke mines, of the Susquehanna Coal Company. The mine surveying, under the supervision of Mr. Thyng, was done partly in the Central Lead Mine, Flat River, and partly in the Prospect Colliery, Wilkes-Barre.

It is regretted that it became necessary to break off the class work in Missouri, as the lead region is an interesting one from both a mining and geological point of view. The methods of mining, and most of the plants, are thoroughly up to date, and close, economical work is the rule. Any description of a district so well known would be out of place in these notes.

In the coal region the students were given opportunity to witness the system of working and the strict precautions necessary in collieries which rank among the most gassy in the world. In the Dorrance mine, underlying part of the city of Wilkes-Barre, and which, although it extends far under the Susquehanna River, is extremely dry and dusty, safety lamps are used everywhere except in the main haulage-ways close to the shaft. The improved Wolff safety lamps have recently been introduced. All the lamps are in charge of two men, for cleaning, filling and regulating, and, as they cannot be unlocked and opened except by means of a large magnet kept in the lamp room, they are much safer, in the hands of careless miners, than the ordinary safety lamps. It is worthy of note that a few days after the class visited the Dorrance colliery a general strike took place because of the introduction of these lamps. One of the chief objections to them, raised by the miners was their weight—about 4 pounds. In this mine, under careful supervision, the class spent two days underground, studying the occurrence of the gas, the mining of the coal, and the systems of transportation. One or two long self-acting planes are in use underground.

At the Maltby colliery an extensive and extremely rapid tail-rope haulage system is in use. It is 6,000 feet long, on moderate grades, and trains of sixteen cars are hauled at a speed of fifteen miles per hour. An endless-rope surface haulage at this mine was also seen by the class. A visit was made afterward to a new compressed air haulage plant in the Glen Lyon mine. At the Exeter colliery the students had the privilege of seeing the operation of sinking a new shaft in a rather wet formation. Several of the most modern steel head-frames were also studied; one of

them at the Sugar Notch mine being under construction at the time of our visit.

It is a pleasure to acknowledge many kindnesses shown us in the coal region by the mine officials, among whom we desire specially to name: Messrs. W. A. Lathrop, General Manager, E. T. Conner, Division Superintendent, John M. Humphrey, Division Engineer, and J. J. Jones, District Superintendent, of the Lehigh Valley Coal Company, and Messrs. Morris Williams, General Manager, and R. Van A. Norris, Mechanical Engineer, of the Susquehanna Coal Company.

ANALYTICAL CHEMISTRY AND ASSAYING.

In the absence of Prof. Ricketts, who is taking his sabbatical year, Dr. Miller is in charge of the quantitative and assay laboratories. Dr. Milier gives the lectures of quantitative analysis to the mining engineers, to the chemists and to all students in assaying. Also to the post-graduate students in inorganic analytical works. The only notable changes in the curriculum are: that the class will take assaying in two sections, one each term, which necessitates a repetition of the lectures, but gives the students much better laboratory facilities than the arrangement in operation for the last two years: that the lectures in quantitative for mining engineers and for chemists have been made entirely distinct this year in order to give the mining engineers more of the short western methods, and the chemists a more scientific treatment of the subject with more attention to the calculations of analytical chemistry.

These changes, made to improve the courses, have been found doubly necessary on account of the great number of new students, graduates from other universities, who have come to take the mining course at Columbia. They would have made classes too large to handle to advantage under the old system.

Dr. H. C. Sherman, formerly assistant in quantitative, and during the past year associated with Prof. Atwater in special work on foods, will give the course in quantitative analysis to the electrical engineers during the first term, and the course on commercial organic analysis to the third-year chemists during the second term.

Dr. Jouët will hold the recitations with the chemists and mining engineers on inorganic quantitative analysis and have special charge of their laboratory work. The new assistants are H. Fisher, a graduate of the School of Chemistry last year, and Barry Hogarty, a graduate of the University of Colorado. They take the places of E. J. Riederer, now with the Repauno Chemical Company and F. S. Hyde, now with the Dixon Crucible Company. It is gratifying to note that the demand for graduates of the Schools of Chemistry and of Mines is far in excess of the supply. E. H. M.

DEPARTMENT OF METALLURGY.

Mr. R. S. McCaffery has resigned the position of assistant, and Mr. A. P. Baumann has been appointed in his place.

The department has received a very great number of important specimens for the museum. Among these may be mentioned three large steel ingots, ten inches square and five feet long, each of them sawn in two

lengthwise so as to reveal the structure, and in particular the prevention of blowholes and the formation of pipe by the addition of aluminium. These are of great educational value, and are among the most important specimens which the museum has ever had. They are the gift of The Benjamin Atha & Illingworth Company through Professor Howe.

The National Tube Works Company also has presented a very important suite of specimens illustrating the manufacture of lap and butt welded pipe, from the ore to the finished product, enclosed in a handsome glass case.

Advantage was taken of the opportunity afforded by the Summer School to collect a great number of important specimens illustrating the metallurgy of steel, lead and copper.

The investigations carried on in the metallurgical laboratory in the past year led to important results. Two of the theses based on these have already been published or accepted for publication, that of O. R. Foster on "The Relative Desulphurizing Effect of Lime and Magnesia in the Iron Blast-Furnace" and that of R. G. Morse on "The Effect of Heat Treatment upon the Physical Properties and the Microstructure of Medium Carbon Steel," both of which will appear in the forthcoming volume of the Transactions of the American Institute of Mining Engineers.

Investigations by post-graduate students will be carried on during the coming year in the metallurgical laboratory on the metallography of the process for making malleable castings, and on the cyanide process.

The Summer School visited the Maryland Steel Works at Sparrow's Point, Md., the Baltimore Copper Works, the Guggenheim smelter, the Balbach Smelting and Refining Works, the New Jersey Zinc Works, both at Bethlehem and at Newark, and the Bethlehem Steel Works, under the charge of Professor Howe and Dr. Struthers.

The department will be deprived after January 1st of the services of Dr. Struthers, who has accepted an important post in connection with the Scientific Publishing Company. The department wishes to record its high appreciation of his more than faithful services, of his wise counsel, of his kindly and considerate co-operation with officers and students, and the example of his zeal, industry, and fidelity, which have been invaluable to all associated with him. H. M. H.

GEOLOGICAL DEPARTMENT.

Two summer schools in geology were held this year by the department. The first passed the first week in June in work upon the igneous rocks of the Cortland series, south of Peekskill, and upon the sedimentary rocks near Rondout. The former portion was under Professor Kemp, the latter under Mr. van Ingen, and some interesting and valuable experience was gained. The second session began in Wilkesbarre, Pa., July 4, with Professor Kemp in charge. Two days were spent in plotting a section of the Wyoming valley at this point. The party then moved to Stroudsburg and occupied two days in studying the geological section in and west of the Delaware Water Gap. The last two days of the session were passed with headquarters at Deckertown, N. J., in work upon the nepheline syenites and their associated rocks at Bennerville and the limestones that lie

west of Hamburg. Professor Kemp then spent the remainder of the vacation in field work in the Adirondacks for the U. S. Geological Survey.

During the early part of the summer Dr. Arthur Hollick was engaged in field work for the Maryland Geological Survey, giving special attention to the fossil plants. Considerable material was collected which will be studied and reported upon to the Survey. The specimens will become the property of the university. Dr. Hollick also received a collection of fossil plants from the Louisiana Geological Survey upon which he has prepared and transmitted a report, accompanied by sixteen plates, which will appear as part of the current annual report of the survey of that state. All the specimens described and figured are, by mutual agreement, now a part of the palæobotanical collection of the university.

Dr. J. S. Newberry's posthumous work on the Later Extinct Floras of North America, edited by Dr. Hollick, has recently appeared as Monograph No. XXXV. of the United States Geological Survey.

Mr. van Ingen devoted a month of the vacation to the study of the lower Ordovician strata of the Champlain Valley under the N. Y. State Paleontologist, Dr. John M. Clarke. Material for an important report was gathered.

Mr. John D. Irving, the retiring fellow in the department, obtained his Ph.D. in June and was immediately appointed to the U. S. geological party under Messrs. Emmons and Jaggar in the Black Hills. Mr. Irving's thesis related to the geology of the Black Hills, and led directly to his appointment. The thesis is now in press with the N. Y. Academy of Sciences. Mr. Theodore G. White also obtained his Ph.D. in June, his thesis being entitled, The Trenton Faunas in the Valley of Lake Champlain. Mr. White is Assistant in the Department of Physics. Mr. B. F. Hill, fellow-elect, spent the vacation in field work, partly for Prof. Kemp, in the Adirondacks and partly in Putnam Co., under the direction of Dr. F. J. H. Merrill, State Geologist.

SCHOOL OF ARCHITECTURE.

The collections of the School of Architecture have lately received some interesting additions. A chief part of the casts already on the walls had been presented to the Metropolitan Museum by Mr. Cornelius Vanderbilt and upon the discontinuance of the Schools of the Museum were, with his cordial consent, presented by the Trustees to the School of Architecture. To these the Trustees have this summer added a fresh consignment, numbering about forty pieces.

The rest of the casts already in hand were the gift of Mr. Charles F. McKim, and consisted, besides casts of sculpture from Florence and from the Roman Forum, chiefly of fragments from the Vika Madonna and from more ancient Roman buildings. To these he has now added a model of the interior of the proposed new Music Hall in Boston. This will presently be set up, in whole or in part, in the Architectural Museum in the upper story of Havemeyer Hall.

Another notable contribution is two large engravings of Trojan's Column and the column of Marcus Aurelius, presented to the School by Mr. Ernest Noel Perrin. These measure, outside the frames, about eleven feet in height, and are a great ornament to our large lecture room. Mr.

Perrin is instructor in English in the College of the City of New York, now studying in our Department of Romance Languages as a candidate for the degree of Ph.D.

Mr. F. L. Pell, of the class of 1895, one of the winners of the McKim Travelling Fellowships, sailed for Europe on the 10th of October, to spend a year in travel and study abroad in accordance with the terms of the Fellowship. Mr. W. E Parsons, of the class of 1897, the holder of the other Fellowship, was already abroad.

ELECTRICAL ENGINEERING DEPARTMENT.

Professor Crocker, after a year's leave of absence, has returned and resumed his lectures. He spent his sabbatical year in making a journey around the world, taking the westerly course and visiting Japan, China, the Philippines, India, France and England. While at Manila the fighting between the insurgents and Americans commenced, he being an interested spectator of the first engagements. During his travels he has contributed to the electrical papers of this country numerous articles on the electrical industries of Japan and China.

The following changes in the teaching staff of this department have occurred this fall:

William H. Freedman, C.E., E.E., has resigned the position of tutor in electrical engineering to become professor of electrical engineering at the University of Vermont. Mr. Freedman was a member of the first class at Columbia (1891) to graduate with the degree of Electrical Engineer and for eight years has rendered most faithful and efficient services in the teaching staff of this department. He has already contributed many articles and the results of experimental investigations to the literature of his profession and will have even better opportunities for such work in his present higher position.

To fill the vacancy created by Mr. Freedman's resignation, S. G. F. Townsend, A B., E.E. ('96), has been promoted, after serving with great credit for three years as assistant. The latter position has been filled by the appointment of C. S. Aylmer-Small, E.E. ('99).

The following investigations formed the subjects of the theses for the members of the class graduating in June, 1899:

Test of the Power Plant of Columbia University.

An Investigation of the Alternating Current Frequency Changer.

Determination of the Temperature Coefficient and Current Carrying Capacity of Commercial Aluminum Wire.

Design of an Alternating Current Electric Lighting Plant for the town of Great Neck, Long Island.

Measurement of the Cyclic Change in Temperature in the Cylinder of a Steam Engine.

Efficiency and Current Harmonics of the Induction Motor.

Cost of Operation of the Horse and Electric Delivery Wagons in New York City.

An Investigation of Asymmetrical Resistances.

The matter contained in the investigation relating to the cost of operation of electric and horse delivery service in New York City was presented before the annual meeting of the American Institute of Electrical

Engineers at Boston in June, the authors being G. F. Sever and R. A. Fliess.

Some additional apparatus, as indicated below, has been purchased by the department during the summer and fall.

Twelve arc lamps of various styles.

Twelve alternating current fan motors, for experimental purposes.

Three lighting arresters, General Electric Co.

Five alternating current inclined coil ammeters.

One 500-ampère Weston ammeter.

One 0–15, 0–150 voltmeter, Weston.

One laboratory telescope, Queen & Co.

One trolley stand. This is one of the first forms employed in railway work and is valuable from a historical standpoint.

The arrangement of the machinery in the alternating current laboratory has been altered in order to give more room for additional machinery, as well as to facilitate the conduct of the work.

F. B. C.

THE COLUMBIA UNIVERSITY CHEMICAL SOCIETY.

This society was organized in December of last year, by a number of officers and students of the chemical department, who desired to hold a series of informal conferences, for the discussion of chemical journal literature. In addition to such journal reviews, however, original papers were also presented and a series of illustrated popular lectures were given. The popular lectures were illustrated by experiments, lantern-slides, specimens, etc., for which purpose all the facilities of the large lecture room and the chemical museum were fully made use of.

Two lectures given by visitors are worthy of special notice. On January 6th Prof. H. van F. Furman gave a lecture on "Western Analytical and Assay Practice," in which he described the requirements of a chemist in the West, and pointed out such analytical methods as were found most commonly in use. On March 23d, Professor Raoul Pictet lectured in French, on "The Influence of Low Temperatures on Chemical Action." He outlined briefly his theory of the constitution of matter, and then proceeded to the subject of the lecture proper, illustrating his remarks by many experiments, showing some of the most active chemical agents to be inert, at low temperatures.

In order to review the current chemical journals with the necessary system, all members formed themselves into seven committees or sections, reporting respectively on one of the following topics: industrial, analytical, organic, inorganic, physical, and physiological chemistry, and metallurgy. The papers were presented by individual members of the several committees. A complete review of some topic of current interest was given, but with special reference to work recently done, and was supplemented wherever possible by experiment and other modes of illustration. In preparing such reports the students were assisted by Professors Chandler, Ricketts and Pellew as well as other officers of the university.

The librarian of the society collects from the members card references to the subjects reviewed and abstracts of original papers presented. This, it is hoped, will become a most valuable adjunct to the work of the society.

The officers of the Chemical Society at present, are:

Hon. President, C. F. Chandler; President, C. E. Pellew; Vice-President, F. J. Pope; Secretary, H. A. Loos; Treasurer, E. W. Scherr; Librarian, O. C. Beck.

Below is given a list of the papers presented during the last year. This will give some idea of the nature of the work done by the Society.

Dec. 2, 1898.—Business meeting for organization.

Dec. 12, 1898.—Knorr's Extraction Apparatus, M. T. Bogert; A new Form of Combustion Furnace, R. S. McCaffery; Notes on the Manufacture of Welsbach Mantles, H. A. Loos; The new Element Etherion, V. Lenher.

Jan. 6, 1899.—Popular lecture, H. van F. Furman, Western Analytical and Assay Practice.

Jan. 16, 1899.—Metallic Carbides, J. A. Mathews; Borscher's Electric Furnace, E. J. Riederer; The Electrolysis of Fused Salts, F. M. Becket; Exhibition of Specimens of Tellurium, V. Lenher.

Feb. 3.—The Manufacture of Potassium Chlorate, S. A. Tucker; a Process for the Manufacture of Copper Sulphate, W. C. Laughlin; the Constitution of Binary and Tertiary Alloys, R. S. McCaffery; an Extension of Friedel and Craft's Reaction, A. H. Gotthelf.

Feb. 17.—Volumetric Indicators, L. W. Hildburgh; the Occlusion of Gases by Metals, W. M. Cobleigh; Some Properties of Liquefied Ammonia, W. M. Cobleigh.

March 3.—Experimental Glass Melting, F. S. Hyde; Aluminum as a Reducing Agent, M. C. Whitaker; Ozone and its Commercial Applications, G. A. Soper; Progress in Photo-chemistry, H. A. Loos.

March 9.—Popular Lecture, "Electro Chemistry," C. F. Chandler.

Mar. 16.—Popular Lecture, S. A. Tucker; "The Electric Furnace."

Mar. 20.—Analytical Processes used in Oil Analysis, H. T. Vulté.

Mar. 23.—Popular Lecture, Raoul Pictet; "The Influence of Low Temperature on Chemical Action."

Mar. 29.—Popular Lecture, P. deP. Ricketts; "Assaying of Gold and Silver and Mint Methods."

Apr. 3.—Popular Lecture, V. Lenher; "Carbonic Oxide and Carbonyl."

Apr. 10.—Popular Lecture, C. E. Pellew; "Calico Printing with Azo-colors."

Apr. 18.—Artificial Silk, C. E. Pellew; Notes on the Occurrence of Vanadium and Titanium, F. J. Pope; The Determination of Bismuth in Lead Bullion, W. C. Laughlin; The Flicker Photometer, H. Fisher.

May 8.—The Preparation of Potassium Percarbonate, R. E. Heike; Some Derivatives of Urea and Carbamic Acid, used in Medicine, W. Cassamajor; Exhibition of Metals Reduced by Aluminium, F. R. Kneeland; Exhibition and Description of Photographs Showing the Influence of Annealing from Different Temperatures on the Microstructure of Steel, C. H. Eckerson and R. S. Morse.

BOOK REVIEWS.

A Primer of the Calculus. By E. SHERMAN GOULD, M. Am. Soc. C. E. D. Van Nostrand Co.; New York. 1899. Second edition, revised and enlarged, 16mo, boards, 122 pages and 24 figures. $0.50.

This booklet is restricted to the absolute rudiments of the calculus. The author attempts very little explanation of the philosophy and logic underlying the fundamental principles of the subject; in fact the few remarks which he makes relating to its theory conclude the essay. He wishes a considerable part of the elementary processes to be taken for granted and at once develops a series of practical applications; his idea being to thereby establish the students' confidence in the correctness of the methods and lead him to a clearer later understanding of the theory.

In the opinion of the undersigned the book cannot be of great value to one who has never studied the calculus because the elements are practically taken as facts and the mind therefore is not well acquainted with the infinitesimal idea. It will certainly help one who did not at the proper time devote himself sufficiently to class-room duties but in such a case any one of the many regular text-books would be of at least equal service.

The greater part of the text relates to the solution of problems. These are well selected and represent mainly problems in pure and applied mechanics which can be solved by the simpler processes of the differential and integral calculus. A number of examples concern themselves with engineering topics such as the reactions and bending moments in beams or the resultant of water pressure on submerged surfaces. The book can therefore be suggestive to the engineering student who is not well grounded in the calculus and its applications.

The theory is based on the infinitesimal method as distinguished from a development of the subject by the theory of limits. This choice is the proper one as it leads to simplicity, the object of the volume.

C. D., Jr.

Hints on Amalgamation, and the General Care of Gold Mills. By W. J. ADAMS, A.M., E.M. Chicago, Modern Machinery Co. 1899. 12mo, 111 pp. Bound covers. 27 illustrations.

Mr. Adams' purpose in writing this work is to present to the public many points of practical interest and value that occurred in his experience and, at the same time, supplementing his experience with a general description of the milling process as applied to gold ores.

The work is not a theoretical treatise, nor is it a detailed description of the mechanical side of the subject. Enough of each has been given to render the work fairly comprehensive for its limited size.

The arrangement of the details of practice has been carefully worked out by the author whose efforts will be appreciated by the reader. Each step is given in its logical order and the author's comments and criticisms interspersed in the text, adds interest to the descriptions and impresse them on the mind with greater distinctness. J. S.

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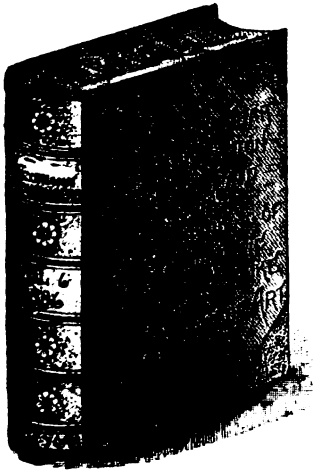

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CONTENTS:

Principles of Alternating Current Distribution. By Francis B. Crocker 93
Engineering Tests on Direct Current Electrical Machinery with Preliminary Tests on the Properties of Conductors. By George F. Sever 113
The Progress of Ore Dressing—II. By C. Blömeke..... 136
The Paradox of the Pantheon. By A. D. F. Hamlin..... 170
A Study on the Metallic Carbonyls and their Decomposition. By Hermann A. Loos and Victor Lenher..... 182
Simple Tables for the Determination of the Common or Economically Important Minerals. By Alfred J. Moses..... 192
Alumni and University News 194

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VOL. XXI. JANUARY, 1900. No. 2.

PRINCIPLES OF ALTERNATING CURRENT DISTRIBUTION.

BY FRANCIS B. CROCKER.

Introduction.—The various principles and facts concerning direct current distribution set forth in the QUARTERLY (Vol. XVIII., Nos. 2, 3 and 4) apply also to alternating current systems. But in addition to the simple phenomena due to resistance, which occur in the former case, there are certain *additional* factors that must be considered in connection with alternating current transmission. The flow of a direct current, which is steady, is entirely determined by the *ohmic resistance* of the various parts of the circuit; and if all these resistances are known the distribution of potential and current can be determined exactly. The flow of an alternating current depends not only upon the resistance but also upon any *inductance* (self or mutual induction) or *capacity* that may be contained in or connected with the circuit. These two factors have absolutely no effect upon a direct current after a steady flow has been established, which usually requires only a small fraction of a second. But in an alternating circuit either or both of them may be far more important than resistance, and in some cases may entirely control the action of the current, the effect of resistance being insignificant.

Since alternating current problems involve a consideration of three factors, they are usually more complicated and difficult to solve than those relating to direct currents. Nevertheless, by an extension of the principles and methods already explained, it will

be found that alternating current systems can be designed correctly and without great difficulty.

Practically the only reason for employing alternating currents in electric lighting is to enable the cost of the conductors to be reduced by using high voltages and transformers. It has already been shown that the cross-section of a wire needed to convey a given amount of electrical energy in watts, with a given percentage of "drop" or loss of potential in volts, is inversely proportional to the square of the E. M. F. employed: hence it requires a wire of only one-quarter the cross-section and weight if the initial voltage is doubled. The great advantage thus obtained by the use of high tension can be realized either by a saving in the weight of wire required or by transmitting the current to a greater distance with the same weight of copper. In alternating current electric lighting the primary E. M. F. is usually at least 1,000 and often 2,000 to 10,000 volts. Even at a pressure of 1,000 volts an advantage of 100 to 1 is gained over a system operating at 100 volts. This enormous difference enables a given number of lamps to be supplied at a far greater distance, and at the same time the conductors weigh very much less. These facts make it unnecessary to design a system of alternating current conductors with the great care that is required for direct current distribution, since the use of slightly larger conductors will make up for any small differences in the arrangement of the feeders and mains. The result is that ordinary alternating current systems of conductors are less complicated than those used for direct currents. The elaborate network of mains, for example, often employed for the latter is seldom required for the former.

On the other hand the actual uniformity of voltage secured on direct-current circuits is usually superior to that obtained on alternating-current systems. This is partly due to the fact just stated, that less care is required in designing the circuits, consequently there is a tendency to exercise too little care. The difference also arises from the effects of inductance and capacity, which produce variations in potential as great as or greater than those due to resistance alone. The exact influence of these factors under various conditions will be considered later.

The reason that the alternating current can be used at the high pressure of 1,000 volts or more, while the direct current is limited to about 120 or 240 volts for constant potential electric lighting is

due to the greater facility with which the alternating current can be *transformed* from a higher to a lower pressure, and *vice versa.* This is accomplished by simple transformers, consisting merely of two or more coils of wire wound upon an iron core. Since there are no moving parts, the attention demanded and the likelihood of the apparatus getting out of order are small. This enables the alternating current to be generated at or transformed to a high pressure suitable for transmission over long distances with small conductors, the potential being locally transformed to that required by the lamps, usually about 50 or 100 volts. In order to convert a direct current from one potential to another it is necessary to employ a motor-dynamo, which is practically a combination of a motor and a dynamo costing considerably more than an alternating current transformer, having a lower efficiency, and being more troublesome to take care of and keep in repair. In almost every other respect the direct current is usually preferable for electric lighting; and where the distances are not great, as, for example, in isolated plants and central stations in thickly populated cities, the direct current has been the system most generally and successfully employed.

Two-phase and three-phase alternating-current systems are often employed to supply incandescent and arc lights but they are only advantageous for operating motors or rotary converters and so far as lamps are concerned they are more complicated and possess no compensating superiority over the single-phase system. The latter, on the other hand, is not desirable when there are a number of motors of anything more than small size, such as fan motors. Hence polyphase systems are used in cases where both lamps and motors are to be supplied with alternating currents.

The principles of alternating currents will now be given, but it is not intended to treat the subject exhaustively as there are several excellent works entirely devoted to it. It is sufficient herein to consider briefly the chief facts to serve as a basis for study and calculations concerning alternating current lines, transformers, etc.

Principles of Alternating Currents.—Each armature coil of a dynamo tends to generate an E. M. F. which rises to a certain maximum value, then falls to zero, then reverses in direction and again returns to zero. This cycle of changes, which can be represented by a curve (Fig. 1), constitutes a complete *period*, and since it is repeated indefinitely at each revolution of the armature in a

bipolar field, the currents produced by such an E. M. F. are called *periodic currents*. The number of complete periods in one second is called the *frequency* of the pressure or current. In Fig. 1 the period is completed in .01 second, hence the frequency is 100. Since the current changes its direction at each half-period, it follows that the number of *alternations* or reversals, is twice the frequency.

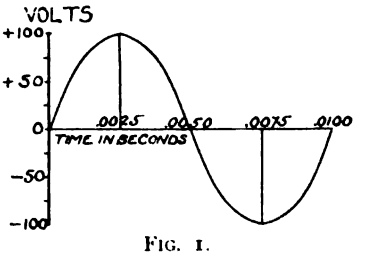

FIG. 1.

Various forms of pressure or current waves may be generated, depending upon the arrangement of the armature winding, pole pieces, etc. It is possible, by having the pole-faces either considerably wider or considerably narrower than the armature coils to produce a *flat-topped wave* (Fig. 2); or by making the coils exactly the same width as the pole-pieces (Fig. 3) a *peaked wave* may be obtained. If the lines of force are excessive at

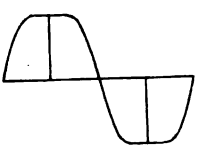

FIG. 2.

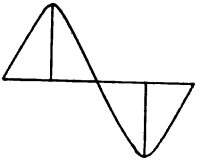

FIG. 3.

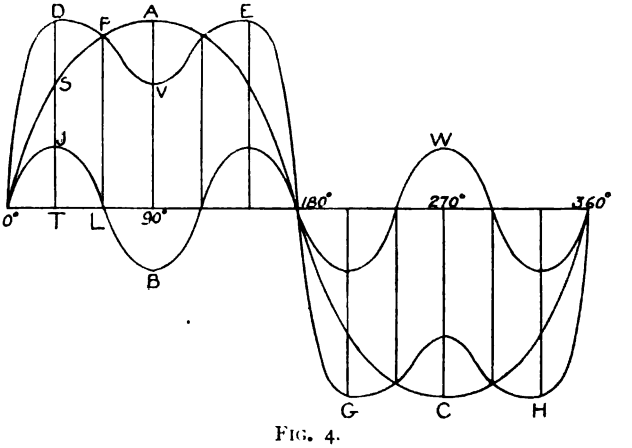

FIG. 4.

the edges of the poles, extra waves or *upper harmonics JBW*, are superimposed upon the main or *fundamental* wave *AC* (Fig. 4). The

extra wave *JBW* shown is the third harmonic, being always an odd number, but in some cases the fifth, seventh or almost any odd harmonic may be present. These harmonics are alternating pressure or current waves of three, five or seven, etc., times the frequency of the fundamental wave *AC*, which are generated simultaneously with the latter and modify its form. In the case represented *DVEGH* is the wave of E. M. F. that is actually produced, being the combination of the fundamental *AC* and the third harmonic *JBW*. For example, the voltage at *D* is the sum of *ST* and *JT*. At *V* it is the algebraic sum of *A* and *B*, and so on. The ideal form of wave generated by a coil of wire revolving about an axis in a uniform field, is the *sine-curve*, in which the E. M. F. at any point *P*, is proportional to the sine of the angle θ through which the coil has moved (Fig. 5).

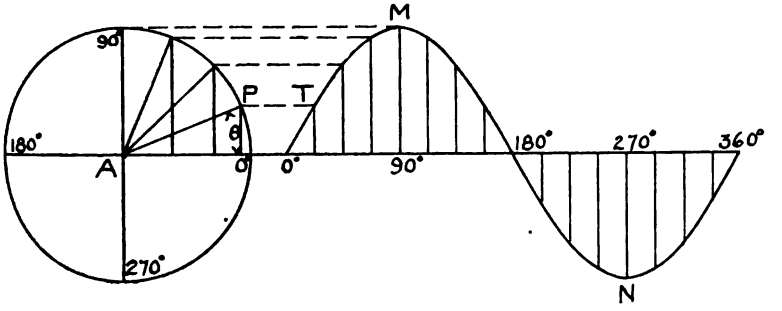

FIG. 5.

If the maximum value at *M* of the E.M.F. is E_{max} then the instantaneous value *e* at any point is

$$e = E_{max} \sin \theta. \qquad (1)$$

When the current wave is also a sine-curve, a similar expression gives the instantaneous value as follows:

$$i = I_{max} \sin \theta. \qquad (2)$$

The sine-wave being the ideal form, practically all calculations are based upon it, other forms tend to be converted into the sine curve, and it seems to be the best for general use, so it should be accepted for the same reason that standard weights and measures, screw-threads, etc., are adopted. This is true even though some other form might have advantages for certain purposes. The

question has been much discussed* but the tendency has been for manufacturers generally to adopt the sine-form, the actual waves of pressure and current in most commercial apparatus being close approximations to the true sine-curve.

If all alternating-current apparatus is designed for the sine-wave it is possible to operate dynamos, motors, measuring instruments, etc., on any circuit, thus avoiding the endless confusion and difficulties that would arise if a different form of wave were adopted by each manufacturer and for each particular purpose.

Effective Values of Alternating Pressures and Currents.—Since the value of an alternating current is continually varying, it is usually more convenient to consider its *mean value*, but this *is not the ordinary arithmetical average*. If an alternating current is flowing through a conductor its heating effect at any instant will be proportional to the square of the current strength, and the average heating effect for the whole time during which it flows will be the average of these squares—that is the mean square. It follows therefore that a direct current to produce the same heating effect would have a value equal to the square root of this quantity, that is $\surd$mean square. The same is true of alternating current E. M. F., since the heating effect is $\frac{E^2}{R}$ so that with a constant resistance the heating is proportional to the square of the voltage. The square root of the mean square of the voltage or current is called its *effective* value and is the quantity which is indicated by alternating current volt- or ampère-meters. For a sine-wave the effective pressure or current is $\frac{I}{\surd 2} = .707$ or about 71 per cent. of the maximum value, and conversely the maximum is $\surd 2 = 1.41$ times the effective value, or 41 per cent. greater. These relations may be summed up as follows:

$$E_{effec} = \surd\text{mean square of } e = \frac{E_{max}}{\surd 2} = .707\ E_{max}; \qquad (3)$$

$$I_{effec} = \surd\text{mean square of } i = \frac{I_{max}}{\surd 2} = .707\ I_{max}. \qquad (4)$$

In practical cases it is usually sufficient to determine the effective volts and ampères of alternating currents, the instantaneous

* *Electrical World*, Aug. 4, 1894, p. 107, and many other issues to Dec. 1, 1894.

values being rarely considered except for the purpose of deducing formulas, studying phenomena and other investigations. The term *virtual* is sometimes applied to the $\sqrt{\text{mean}^2}$ values instead of effective, but the latter word is now generally adopted.

Inductance is one of the three fundamental quantities which affect the flow of an alternating or other varying current, the other two being resistance and capacity. It is due to inductive action of the circuit on itself, or of one portion of the circuit on another portion of the same circuit, in which case it is called *self-induction;* or it may be due to the action of one circuit upon some portion of another independent circuit, in which case it is called *mutual-induction.* The former is the one generally considered in transmission, and will be treated first.

The unit of inductance, or the "coefficient of self- or mutual induction," is called the *henry*, which is the inductance of a circuit when the E. M. F. induced in it is one volt while the inducing current varies at the rate of one ampère per second. For example, if a counter E. M. F. of one volt is set up in a coil when the current is increased at the rate of one ampère per second, then the self-inductance of that coil is one henry.

The physical cause of the phenomenon of self-induction is the fact that a current flowing in a conductor tends to produce magnetic lines of force around itself. If the conductor is a helix of wire, the lines produced by each turn pass through that turn and most of the others, so that the total flux through the helix is large. When the current varies the lines of force also vary in number and necessarily cut the turns of wire, thereby setting up an E. M. F. in the latter. With increasing current this E. M. F. is counter and opposes the flow, with decreasing current it aids it, but when the current is steady no E. M. F. is induced since the lines of force do not vary or cut the conductor. In the case of mutual induction, it is evident that a second coil B in the neighborhood will be cut by the lines of force produced by the first, tending to set up an E. M. F. in B which will cause a current to flow in it or will oppose or aid a current already flowing according to the relative directions of the lines of force and the current.

Inductance was defined by the Chicago Electrical Congress of 1893 in terms of the E. M. F. generated, but it is also proportional to the number of turns of wire and to the average flux through each when unit current is flowing. This is similar to the first

definition since the production of a certain number of lines of force by one ampère in one second tends to generate a certain E. M. F.

A third definition of inductance may be based upon the electromagnetic energy stored in a coil when a unit current is flowing, which energy is proportional to the square of the flux density, other things being equal.

These three definitions may be summed up as follows:

Three Definitions of Inductance.—Calling L the inductance in henrys, e and i the instantaneous values of the E. M. F. in volts and the current in ampères respectively, n the instantaneous value of the average flux through each turn of wire, Z the number of turns, W the energy in joules and $\frac{di}{dt}$ the time rate of variation of the current, we have:

in terms of E. M. F.

$$e = L\frac{di}{dt} \tag{5}$$

in terms of lines of force and turns of wire

$$\frac{10^8}{nZ} = Li \tag{6}$$

in terms of energy

$$W = \tfrac{1}{2} Li^2. \tag{7}$$

Reactance due to Self-induction.—It has been shown that the effect of inductance in an alternating current circuit is to oppose the flow of current on account of the counter E. M. F. which it sets up. This opposition may be considered as an *apparent resistance* and is called *reactance* to distinguish it from true ohmic resistance. The value of the reactance due to inductance is given by the following expression in which f is the frequency in periods per second, and L is the inductance measured in henrys

$$\text{Reactance} = 2\pi fL \tag{8}$$

The result obtained gives the equivalent or apparent resistance in ohms.

Example.—A coil of wire having a self-inductance of 25 millihenrys = .025 henry is supplied with an alternating current at a frequency of 100 periods per second. Its reactance assuming its ohmic resistance to be negligible, would be

$$2\pi fL = 2 \times 3.1416 \times 100 \times .025 = 15.7 \text{ ohms.}$$

Such a coil would have the same apparent resistance as a non-inductive circuit of 15.7 true ohms, and if connected to an alternating current supply giving 1000 volts at 100 frequency, the current flowing through the coil would be $\frac{1000}{15.7} = 63.6$ ampères.

Impedance due to Resistance and Inductance.—Actual circuits always have resistance as well as inductance, and in most cases the former cannot be neglected. The combined effect of resistance and inductance is called *impedance* to distinguish it from the other two, and has the following value in ohms (apparent resistance).

$$\text{Impedance} = \sqrt{R^2 + (2\pi fL)^2}. \qquad (9)$$

Example.—A coil of wire has a resistance of 20 ohms and an inductance of .025 henry. For an alternating current having a frequency of 100 the impedance of the coil is

$$\sqrt{R^2 + (2\pi fL)^2} = \sqrt{20^2 + 15.7^2} = 25.4 \text{ ohms},$$

Supplied with 1000 volts the coil would receive a current of $\frac{1000}{25.4} = 39.3$ ampères.

The relations expressed analytically in (9) are evidently represented graphically by the right-angle triangle in Fig. 6. The resistance in ohms is laid off on a convenient scale to form the base, the reactance is laid off also in ohms to form the perpendicular, and the impedance in ohms is found by measuring the hypothenuse of the triangle.

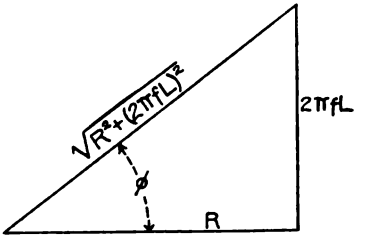

FIG. 6.

Lag of Current due to Inductance.—Besides opposition or reactance to an alternating current, inductance also causes the latter to lag behind the E. M. F. which produces it. The curve *E F* in Fig. 7 represents the waves of an alternating E. M. F. impressed upon a circuit containing ohmic

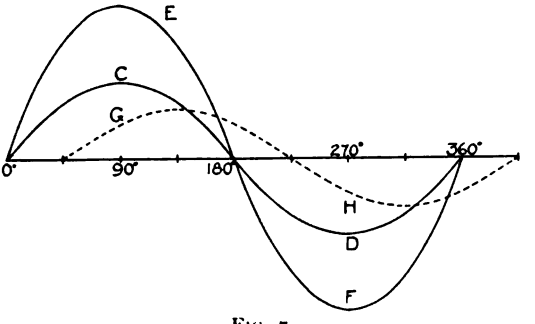

FIG. 7.

resistance without inductance or capacity. In such a case the resulting current will reach its maximum as well as zero values

at the same instants as the E. M. F. and may be represented by the curve *C D*. If now a self-induction coil be introduced into the circuit in series with the resistance, the current waves will lag with respect to those of E. M. F., that is, the maximum current will flow a little later than the instant of maximum E. M. F., as indicated by the dotted curve *G H*. The amount of this lag is measured as an angle called the *angle of lag*, assuming one complete period to correspond to 360°. In Fig. 7 the current wave is shown as having its zero value one-eighth of a period or 45° behind the zero E. M. F. and the same for the maximum and other corresponding points.

The tangent of the angle of lag with a given resistance R and inductance L in the circuit is

$$\tan \varphi = \frac{\text{reactance}}{\text{resistance}} = \frac{2\pi fL}{R}. \qquad (10)$$

Referring to Fig. 6, it is evident that the tangent of the angle φ is equal to $2\pi fL \div R$, therefore φ represents the angle of lag, which may be easily determined graphically in this way. It is apparent from Fig. 6 that the angle of lag φ is small if the resistance is large compared with the inductance L unless the frequency is high. It is a fact also that however large the inductance or frequency and however small the resistance, the angle of lag can never be greater than a right angle or 90°. This is evident in (10) since $\varphi = 90°$ when its tangent is infinity.

Example.—A circuit has a resistance of 2 ohms and an inductance of .0016 henry. What is the angle of lag for an alternating current having a frequency of 100?

$$2\pi fL = 2 \times 3.1416 \times 100 \times .0016 = 2 \text{ ohms.}$$

The resistance R is also 2 ohms, therefore $\tan \phi = \frac{2}{2} = 1$ and ϕ is 45°. This is the condition shown in Fig. 7, the current wave *GH* (dotted) being 45° behind the E.M.F. wave *EF*. The curve *CD* represents the current that would flow if a wire of 2 ohms resistance without inductance were supplied with 100 volts alternating E.M.F., the current at any instant having one half the numerical value of the E. M. F. its effective value being $100 \div 2 = 50$ ampères with no lag. The addition of .0016 henry inductance produces a reactance of 2 ohms which, combined with the resistance of 2 ohms, makes an impedance of $\sqrt{2^2 + 2^2} = 2.82$ ohms which is much less than their arithmetical sum.

The current is $100 \div 2.82 = 35.5$ ampères, so that the effect of inductance is to diminish the current and cause it to lag as shown by comparing curves *CD* and *GH* in Fig. 7.

Determination of the Power of an Alternating Current.—In a circuit containing ohmic resistance only, the current wave *C* does not lag

with respect to the E. M. F. wave E, and the power is represented by the curve PQ in Fig. 8. At any instant the power in watts is

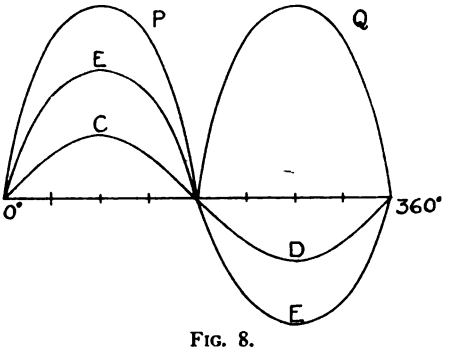

FIG. 8.

the product of the E. M. F. and current at that instant, but for convenience these values (curve PQ) are plotted on a smaller scale than E and C. The power is positive at all times since the product of the positive values of E and C as well as the negative values of D and F are always positive, and its effective value is the $\sqrt{\text{mean}^2}$ of these products, which is simply the product of the effective E. M. F., E and current I, as read on a volt- or ampère-meter, that is

$$\text{Power} = E \times I.$$

With inductance in the circuit, the current lags behind the E.M.F. and the power may be represented by the curve $PRQS$ in Fig. 9. The negative values R and S of the power are due to the fact that

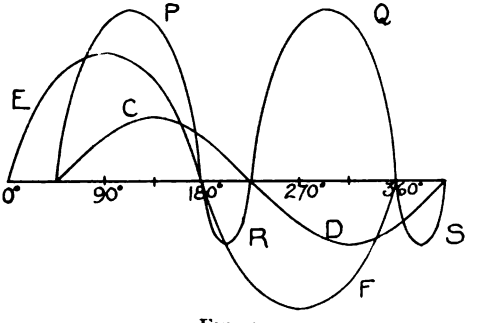

FIG. 9.

the current C is positive when the E. M. F. is negative or *vice versa*, hence the actual power is reduced, being the algebraic sum of these

quantities. When the reactance is very great compared with the resistance the current lags 90° and the negative power at T and U in Fig. 10 is equal to the positive power at P and Q so that the actual power is zero. All that occurs is a charging and discharging of electro-magnetic energy in the coil, the amount returned being equal to that stored. It should be noted that the frequency of the power curves in Figs. 9 and 10 is twice that of

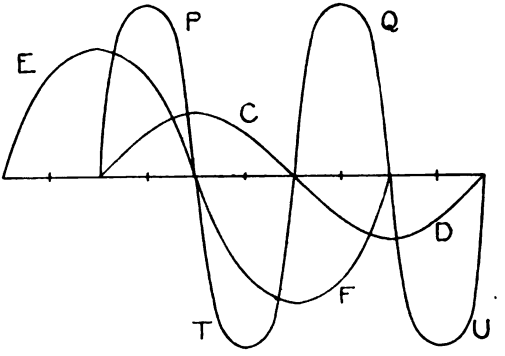

FIG. 10.

the E. M. F. or current. The effective power when the E. M. F. and current differ in *phase*, that is, one lags behind the other, is

$$\text{Power} = EI \cos \varphi. \qquad (11)$$

In this expression cos φ is the cosine of the angle of lag and is called the *power factor* since it is the ratio of the *real power* to the *apparent power EI*.

To measure alternating current power it is necessary to know the angle of lag if separate volt- and ampère-meters are used or to use a watt-meter which gives the true reading directly.

Example.—Taking the same case as before in which the E. M. F. is 100 volts, the current is 35.5 ampères and the angle of lag is 45°, the real power would be $100 \times 35.5 \times \cos 45^\circ = 100 \times 35.5 \times .71 = 2520$ watts, while the apparent power is $100 \times 35.5 = 3550$ watts.

Capacity is the third quantity which affects the flow of an alternating or other variable current. This physical quantity is familiar in the case of the electrostatic capacity of a Leyden jar or a condenser, and is measured in terms of the *farad* as a unit, being the capacity of a condenser which will contain one coulomb of charge at a potential of one volt. Since this unit is much too large for

ordinary use, the *microfarad* or millionth of a farad is generally employed.

Reactance due to Capacity.—When the two terminals F and G of a condenser are connected respectively to the two wires BD of an alternating current source A, as indicated in Fig. 11, the condenser will be charged and discharged continually so that current will flow in the wires B and D in spite of the fact that the two sides F and G of the condenser are insulated from each other which prevents actual passage of current through the condenser. In fact, a given condenser is equivalent to a closed circuit having a certain resistance, or, in other words, it has an apparent resistance in ohms which is called its reactance, corresponding to that due to inductance. Evidently the flow of current increases directly with the capacity and with the frequency, therefore the reactance is inversely proportional to these quantities. Calling K the capacity in farads, the reactance in ohms is:

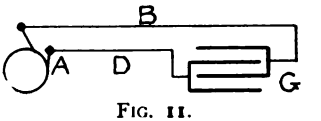

FIG. 11.

$$\text{reactance} = \frac{1}{2\pi f K}; \tag{12}$$

$$\text{current} = E \times 2\pi f K. \tag{13}$$

Example.—What is the reactance of a 50-microfarad condenser to an alternating current of 100 frequency? The reactance from (12) is:

$$\frac{1}{2\pi f K} = \frac{1}{2 \times 3.1416 \times 100 \times .000050} = \frac{1}{.031416} = 31.8 \text{ ohms.}$$

If the E. M. F. of the supply is 100 volts, a current of $\frac{100}{31.8} = 3.14$ amperes would flow in the connecting wires.

Lead of Current due to Capacity.—A condenser is supplied with an alternating E. M. F. represented by the curve $EFGH$ in Fig. 12. It is evident that current will flow into the condenser in one direction while the E. M. F. varies from its greatest negative value E to its highest positive value F, and its direction is the same as that of the positive E. M. F., therefore, a positive wave of current C is produced during that time. The condenser is fully charged when the E. M. F. reaches its maximum value F, so the flow into the condenser

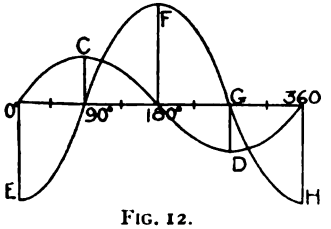

FIG. 12.

ceases and the current is zero. The E. M. F. then falls as shown by the line *FGH*, and the condenser discharges producing the negative current wave *D* and so on. By comparing the two curves, it appears that the maximum current into the condenser occurs at a point *C* which is 90° *ahead* of the maximum E. M. F. at *F*, and the same for other corresponding points. Hence, the charging current of a condenser has a *lead* with respect to the impressed E. M. F. The tangent of the angle of lead or negative lag is given by an expression analogous to (10).

$$\tan \varphi = -\frac{\text{Reactance}}{\text{Resistance}} = -\frac{\frac{1}{2\pi fK}}{R} \qquad (14)$$

This angle may be determined graphically by a triangle, as indicated in Fig. 13, similar to Fig. 6, but in this case the reactance $\frac{1}{2\pi fK}$ id off downward, since it produces a lead instead of a lag.

Impedance due to Resistance, Inductance and Capacity.—When a certain ohmic resistance is in series with a condenser, the impedance or combined apparent resistance in ohms is given by an expression corresponding to (9).

$$\text{Impedance} = \sqrt{R^2 + \left(\frac{1}{2\pi fK}\right)^2} \qquad (15)$$

The same result is obtained graphically in Fig. 13. When inductance and capacity are both present in a circuit, the reactance

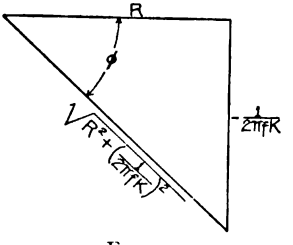

FIG. 13.

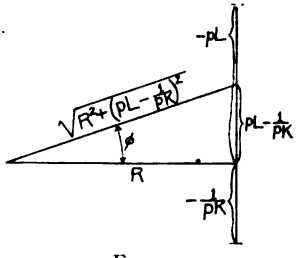

FIG. 14.

of one tends to balance that of the other so that the combined reactance is the algebraic sum of the two, that is:

$$\text{Reactance} = 2\pi fL - \frac{1}{2\pi fK} \qquad (16)$$

when all three quantities—resistance, inductance and capacity—are present in a circuit the combined impedance is

$$\text{Impedance} = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fK}\right)^2}\,; \qquad (17)$$

$$\text{Angle of lag or lead} = \frac{2\pi fL - \frac{1}{2\pi fK}}{R}. \qquad (18)$$

The graphical solution is shown in Fig. 14, the inductance reactance being laid off upward and the capacity reactance downward, the difference being the perpendicular of the triangle of which the hypothenuse is the impedance and the angle φ is the lag or lead as the case may be. For convenience the constant $2\pi f$ is designated as p.

Example.—A circuit consists of a coil having 20 ohms resistance and .025 henry inductance in series with a condenser of 50 microfarad. What is the combined impedance and angle of lag when supplied with alternating current at a frequency of 100? The impedance from (17) is $\sqrt{20^2 + (15.7 - 31.8)^2} = 25.6$ ohms which is less than the capacity-reactance (31.8 ohms) alone. The tangent of the angle of lead (the capacity-reactance being greater than the inductance-reactance) is

$$\frac{15.7 - 31.8}{20} = -\frac{16.1}{20} = -.805.$$

Power Factor with Resistance, Inductance and Capacity.—It has already been stated (11) that Power $= EI \cos \varphi$ when the current lags on account of inductance. It applies also to a leading current in a capacity circuit, and to a circuit containing resistance, inductance and capacity. All that is necessary is to determine the angle of lag or lead from (18) or Fig. 14 and the cosine of that angle is the power factor. It is evident in (18) and Fig. 14, that the angle of lag φ is small when the induction and capacity reactances are nearly equal, so that they practically neutralize each other, in which case $\cos \varphi$, the power factor, is almost 100 per cent

Resonance.—If $2\pi fL = \frac{1}{2\pi fK}$ in (17), then

$$LK = \frac{1}{(2\pi f)^2} \qquad (19)$$

and the impedance of the circuit reduces to R simply, just as if neither inductance nor capacity were present. In other words the two reactances exactly neutralize each other. The electrostatic

energy in the condenser discharges when the electromagnetic energy in the inductance is being stored up, and *vice versa*. This condition is called electrical *resonance* and the circuit is said to be *tuned* for the particular frequency indicated in (19), since with a given E. M. F., the current will be much stronger for that frequency than for any other, the impedance being a minimum and equal to the resistance only. The induction- or capacity-reactance may each be very high, in which case the difference of potential across either pair of terminals will be much greater than the impressed E. M. F., since the drop in voltage for each part of the circuit is equal to its reactance multiplied by the current. This can best be made clear by an example.

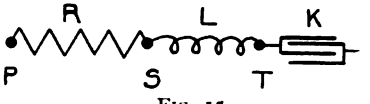

FIG. 15.

Example.—In Fig. 15 a non-inductive resistance R of 2 ohms is connected in series with a coil L having .051 henry inductance (with insignificant resistance) and with a condenser K of 50 microfarads. What are the conditions when 100 volts alternating E. M. F. at 100 frequency is applied to the terminals P and U? The impedance from (17) is $\sqrt{2^2 + (32. - 31.8)^2} = \sqrt{4 + .04} = 2.01$ ohms. This is only .01 ohm or one-half of one per cent. more than the resistance alone. With 100 volts the current is $100 \div 2.01 = 49.8$ ampères. Since the reactance of the coil L is 32 ohms, the potential difference across its terminals S and T is $32 \times 49.8 = 1593.6$ volts and between the terminals T and U of the condenser K it is $31.8 \times 49.8 = 1583.6$ volts. Each of these is nearly sixteen times as great as the impressed voltage at P and U which is only 100. This multiplication of pressure when resonance happens to occur is sometimes the cause of breakdown in the insulation of conductors and apparatus.

Circuits Containing Reactances in Series.—Equation (17) or the graphical methods shown in Figs. 6, 13 and 14, may be used to find the impedance of any combination of resistances, inductances or capacities in series. In such a case the sum of all the resistances should be substituted for R, the sum of all the inductances for L and the sum of all the capacities for K in (17). These total values may be used also in the diagram represented in Fig. 14. The E. M. F. is then divided by the total impedance thus found in order to obtain the current. The potential difference between any two points of the circuit is the product of this current and the impedance between those points. The angle of lag is found by (18) using total values for R, L and K. If one or two of these quantities are not present in any case, they disappear from the equations or graphical representations without affecting those quantities remaining.

Reactance E. M. F.—In Fig. 16 the horizontal line *OA* is laid off in proportion to the resistance of a certain coil, and the vertical line *OB* is made proportional to its reactance $= pL$, in which

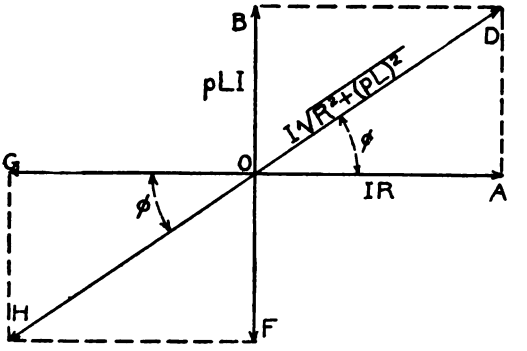

FIG. 16.

$p = 2\pi f$. When the rectangle is completed, the diagonal *OD* represents the impedance $= \sqrt{R^2 + (pL)^2}$, being the same as the hypothenuse in Fig. 6. Assuming a current of one ampère in the coil, the voltage across its terminal is $I\sqrt{R^2 + (pl)^2}$, which is numerically equal to the impedance, hence the line *OD* in Fig. 16 may be taken to represent that voltage. Similarly the line *OA* gives the drop due to the ohmic resistance, and the line *OB* shows the voltage required to overcome the reactance. That is, the impressed E. M. F. *OD* is resolved into two components at right angles to each other, one of which, *IR*, overcomes the resistance, and the other, *pLI*, overcomes the reactance. The reactance is, in fact, an opposing E. M. F., having an effective value, *OF*, equal but directly opposite to *pLI* and lagging 90° behind the current, the phase of the latter being represented by the line *OA*.

These relations, which are very important, may be stated as follows: With a given current *I* the effect of resistance is equivalent to a counter E. M. F. equal to *IR* and represented by the line *OG*. With the same current, the reactance is actually an opposing E. M. F. having an effective value equal to *pLI* and indicated by *OF*. The combined effect of the two is equivalent to a counter E. M. F. equal to *OH* which is their resultant. Hence *OD*, the impressed E. M. F., must exactly balance *OH*, that is, it is equal and opposite as shown. The phase of the impressed E. M. F. is represented by the line *OD* with respect to which the current

phase OA has an angle of lag φ, and OF the reactance E. M. F. has a further lag of 90° behind the current.

Precisely similar diagrams and reasoning apply to the capacity reactance and angle of lead in Fig. 13 and to the combined inductance and capacity reactances in Fig. 14.

Composition and Resolution of E. M. F. and Current.—In the manner explained above, two or more alternating E. M. F.'s may be combined to form a resultant, or one E. M. F. may be resolved into two or more components, and the same is true of alternating currents. For example, two alternators are running in series, the value and phase of the E. M. F. of one being represented by OM in Fig. 17 and the value and relative phase of the other's E. M. F. being represented by ON. The combined effect is the same as that of one E. M. F. having the value and phase OP which is the resultant of the two. If OM and ON represent the phase

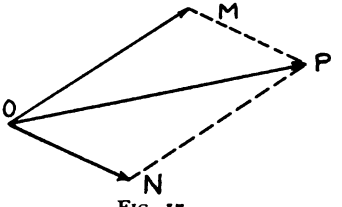

FIG. 17.

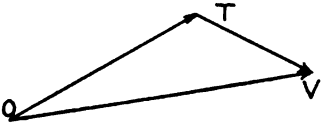

FIG. 18.

and values of two alternating currents the phase and amount of the resultant current are given by OP. This method applies to any number of E. M. F.'s or currents having any phase angles, the various components being combined successively in pairs. Instead of constructing a complete parallelogram, it is sufficient to lay off OT to represent one E. M. F. and TV to represent the phase and value of another E. M. F., then OV is their joint phase and amount. In other words, their resultant is the vector sum OV of the two vectors OT and TV representing their respective values and phases.

Impedance of Parallel Circuits.—With two or more simple ohmic resistances in parallel, the joint conductance is the sum of the several conductances, hence the joint resistance is the reciprocal of the sum of the reciprocals, that is:

$$R = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \cdots}. \qquad (20)$$

In the above, R is the joint resistance of the resistances r_1, r_2,

etc., in parallel. If no inductance or capacity is present this is true of alternating circuits, and always applies to steady direct currents. When there is inductance or capacity or both in one or more of several alternating circuits in parallel, it becomes necessary to consider the phases of the currents in the different branches. Two inductive coils A and B in parallel are assumed to be supplied with an alternating voltage by the conductors C and D in Fig. 19. To deduce a method for finding their joint impedance,

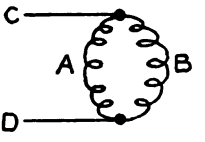

FIG. 19.

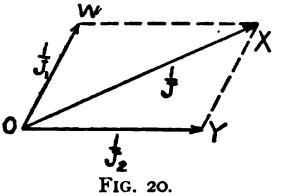

FIG. 20.

let us suppose that OW in Fig. 20 represents the phase and value of the current in the coil A and OY the phase and value of the current in B, then OX gives the phase and value of the resultant current, which actually flows on the supply wires C and D. If the effective potential difference between C and D is one volt and the impedance of the coil A is J_1 then its current OW is $\frac{1}{J_1}$ and if the impedance of B is J_2, its current OY is $\frac{1}{J_2}$. The resultant current OX must be $\frac{1}{J}$ in which J is the joint impedance of the two. The reciprocal of impedance is called *admittance*, therefore, *the joint admittance of two or more alternating circuits in parallel is the resultant of their several admittances.* The equivalent impedance is found by taking the reciprocal of the joint admittance. Many combinations of resistance, inductance and capacity in series and in parallel are calculated out in the work on "Alternating Currents," by Professors D. C. and J. P. Jackson, pp. 151–220. The following examples are sufficient to show the method:

Examples.—A non-inductive resistance R_1, of 10 ohms is in parallel with an inductive resistance of 10 ohms and .01 henry as indicated in Fig. 21. What is the joint impedance and angle of lag for an alternating current having a frequency of 127½? The impedance of the lower branch may be determined by constructing the triangle shown in Fig. 22 in which the base $= R_2 = 10$ and the perpendicular $= 2\pi fL = 800L = 8$. Hence, by calculation or by measurement we find

that the impedance $J_2 = 12.8$ and the angle of lag $\phi_2 = 38°40'$. In another diagram (Fig. 23) the conductance $= \frac{1}{R_1} = .100$ is laid off horizontally to represent the

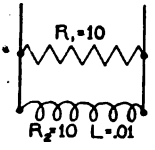

FIG. 21.

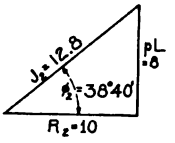

FIG. 22.

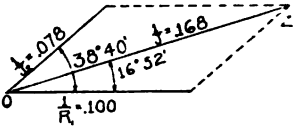

FIG. 23.

upper branch and the admittance $= \frac{1}{J_2} = .078$ is laid off at an angle $\phi_2 = 38°40'$ to represent the lower branch. Completing the parallelogram it is found that the joint admittance $= \frac{1}{J} = .168$ so that the joint impedance $J = 5.95$ ohms and the resultant angle of lag $\phi = 16°52'$. In Fig. 24 a coil $R_1 = 10$ ohms and $L = .01042$ henry is in parallel with a circuit containing a resistance $R_2 = 10$ ohms and a condenser having a capacity $K = 150$ microfarad, what is the joint impedance and angle of lag ϕ for an alternating current having a frequency of 127½? The impedance of the coil is found

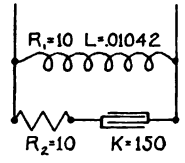

FIG. 24.

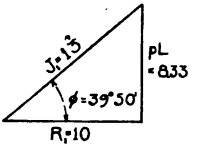

FIG. 25.

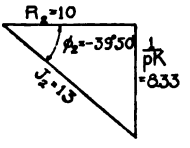

FIG. 26.

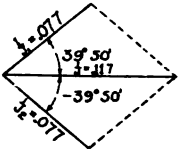

FIG. 27.

to be $J_1 = 13$ ohms and the angle of lag $\phi_1 = 39°50'$ in Fig. 25 and the impedance of the condenser circuit is $J_2 = 13$ ohms and the angle of lead $\phi_2 = -39°50'$ in Fig. 26. The corresponding admittances, each of which is $1 \div 13 = .077$, are laid off in Fig. 27 with the same angles of lag and lead. The joint admittance $\frac{1}{J} = .117$ so that the joint impedance $J = 8.47$ ohms, and the resultant angle of lag $\phi = 0$, since the lag of one circuit balances the lead of the other. At 100 volts the main conductors F and G would supply $100 \div 8.47 = 11.7$ ampères. The power factor is 100 per cent. ($\cos \phi = 1$) so that the true power would be $100 \times 11.7 = 1170$ watts. The current in each branch would be $100 \div 13 = 7.7$ ampères, one lagging $39°50'$ and the other leading $39°50'$ with respect to the impressed E. M. F. The fact that the actual current supplied ($= 11.7$ ampères) is not equal to the sum of those in the two branches ($2 \times 7.7 = 15.4$ ampères) shows that the discharging of one partly acts to charge the other which is always the case when parallel circuits are not in the same phase.

Other combinations of resistance, inductance and capacity may be treated in a similar manner.

ENGINEERING TESTS ON DIRECT CURRENT ELECTRICAL MACHINERY WITH PRELIMINARY TESTS ON THE PROPERTIES OF CONDUCTORS.

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Introduction.

1. In presenting the following matter two purposes have been held in view, the first one being that it should be adapted for students in engineering courses who do not make a specialty of electrical engineering, but who, in the subsequent pursuit of their professions, might be called upon to pass upon the merits of such types of machines as are herein referred to; the second one is, that those who are at present pursuing the engineering profession in its various branches and are familiar with the use of electrical engineering measuring instruments and apparatus may find the description of the methods of dynamo and motor operation and testing, herein contained, to be of sufficient value to warrant their more extensive use. The operation and testing of direct-current dynamos and motors is so much simpler than the testing of a steam engine and many other forms of apparatus employing steam, that any engineer with a general knowledge of electrical engineering and by the use of standard electrical measuring instruments can determine the various losses in dynamos and motors and therefrom their commercial efficiencies. It is often desirable that this be checked under various conditions and in comparison with the manufacturer's rating. This can be done by using either the Prony brake or "stray power" method as the conditions demand. The following tests are at present assigned to the third-year civil and mining engineers at Columbia University and constitute part of their instruction under the Department of Electrical Engineering.

General Instructions.

2. Before commencing any experiment or test, its description should be carefully studied in order to obtain a clear understanding of its object and the method of procedure. By gaining a complete

understanding of the purpose of an experiment or test before commencing upon the actual work, a much more satisfactory comprehension of its results can be obtained. There is also less likelihood of taking unnecessary readings and of omitting others of importance, thereby impairing the value of the results.

Engineering practice demands that a systematic record of all original observations be kept during the progress of a test. In order to follow this, all instrument readings should be placed in a note-book immediately upon being observed. It is advisable to previously prepare a tabulated form in which these observations can be entered, thereby insuring neatness and the recording of corresponding readings in such a manner as to prevent confusion and error in deducing the final results. In the completed report the original data and deduced results should be entered and properly designated.

Presentation of Report.

3. An engineering report should be as complete as the circumstances demand, its workmanship should be neat, its opinions clear and concise and its statements exact, so that there can be no question as to the meaning conveyed. Drawings, diagrams and graphical representations of results should be executed in the best possible manner. An engineering report is often taken as a criterion of the ability of the engineer and therefore should demand from him his best endeavors.

The report of a test should include the following matter:

1. A clear statement of the object of the test with an explanation of the method of procedure.

2. A description of all the apparatus used.

(Designate all machines by their names, types and capacities and all instruments by their numbers, types and capacities. It is important to note any errors due to the displacement of the pointer or needle of the measuring instruments.)

3. All original observations and data. All deduced results. All important calculations in detail. Curves (when necessary) illustrating graphically the relation existing between the various quantities.

If original observations and deduced results are capable of such arrangement, they should be neatly tabulated.

4. Conclusions deduced from the results of the test and the reasons leading up to these should always be included.

5. A diagram or diagrams of the arrangement of all apparatus, including electrical connections, the various pieces of apparatus being properly designated by letter or name.

Instructions for Plotting Curves.

4. Curves are employed to illustrate graphically the relations which exist between the values of two variable quantities. The values of one quantity are used as the ordinates while the corresponding values of the other are used as the abscissas of the curve.

In order that the curve may properly represent the correct relation of the two variables, it is necessary to select a proper ratio between the scales of the ordinates.

A curve need not follow exactly the observed or calculated points, but will usually follow a mean path through these points. Any point departing widely from this average path is probably an error in observation and it may be necessary to go over that part of the work to ascertain whether or not this point is actually an error or is a characteristic of the phenomenon under investigation. The curve which expresses the relation between two uniformly varying variable quantities is a smooth one and any point departing widely from its path is undoubtedly plotted from an incorrect observation.

Use of Instruments.

5. Before connecting the instruments to a circuit, adjust the quantities to be measured—current, pressure or power—to such values that they lie within the capacity of the instruments to be used. If this precaution is not taken, the pointer or needle is liable to be bent and the instrument, especially in the case of a voltmeter, to be burned out.

Instruments should not be used in close proximity to dynamos, motors or conductors carrying large currents, for readings are affected by magnetic leakage from these sources, and the steel magnets in the instruments are liable to be permanently changed.

When instruments are placed upon tables or benches, the conductors leading to them should be secured to some point so that the instruments may not be pulled off and so suffer damage by falling upon the floor.

Do not handle instruments *roughly*, for such treatment is liable to dull the pivots or break the jewels which form the bearings.

When using any instruments with metallic covers do not allow the conductors to touch the cover, for the needle of these instruments may be connected to one side of the circuit and if wires from the other side should make contact with the cover, a short circuit may be caused by the needle touching the cover at the end of its swing.

When instruments are left continuously in circuit, the heating error comes in and must be allowed for.

When using a voltmeter and an ammeter for measuring the resistance of an *inductive circuit*, always *disconnect* the *voltmeter before* opening the circuit, otherwise the inductive discharge will injure the instrument.

Table of Symbols.

6. The recommendations of the International Congresses and the Standardization Report of the American Institute of Electrical Engineers have been adopted in forming the following table of symbols.

At = ampère turns.

$\mathbf{B}$ = magnetic density in lines of force per unit area.

b = breadth, width.

γ = electrical conductivity.

C, c = current in ampères.

C_{se} = current in series field.

C_{sh} = current in shunt field.

C_f = total current in fields.

C_t = total current delivered to or by a machine.

D, d = diameter.

E, e = electromotive force, voltage, potential difference.

ε = eddy current coefficient.

$\mathbf{F}$ = magnetomotive force, in *Gilberts*. M.M F.

F, f = force or pull in pounds or kilograms.

Φ = total magnetic flux in magnetic circuit under consideration, in *Webers*.

$\mathbf{H}$ = magnetizing force per unit length, in *Gausses*.

h = height or thickness.

HP = horse-power.

η_i = hysteresis factor.

Eff = commercial efficiency.

J = Joule's mechanical equivalent of heat.

K = constant.
L, l = length or distance.
M = mass or volume.
μ = magnetic permeability.
N = number of revolutions per minute.
n = number of inductors in series on armature.
P = electrical power at the terminals of a machine in *Watts*, output of generator, input of motor.
p = no. of pairs of poles.
$\mathbf{R}$ = reluctance (magnetic resistance) of magnetic circuit, in *Oersteds*.
R = electrical resistance, in *Ohms*.
S = surface or area.
T = time.
t = temperature.
T = torque or turning moment in ft. lbs.
v = velocity, linear speed.
W, *wt.* = weight.

7. General Equations.

Electrical Circuits.—

Ohm's law is as follows: "The strength of the current varies directly as the electromotive force and inversely as the resistance of the circuit"

or $$C = \frac{E}{R}.$$

Also $$E = CR, \quad R = \frac{E}{C}$$

C = current in *amperes*,
E = EMF in *volts*.
R = resistance in *ohms*.

The resistance (R) of a conductor varies directly as its length (l) and inversely as its cross section (S) and conductivity (γ); or $R \propto \frac{l}{S\gamma}$.

The power or rate of expenditure of energy, in *watts* or *kilo-watts*, in any electrical circuit carrying direct current, is $P = CE = C \times CR = C^2R =$ watts.

1 HP = 746 watts.
1 kilo-watt = 1.34 HP.

The amount of energy in the form of heat expended in a circuit in (T) seconds is measured in *Calories*. Denoting time in seconds by (T), and Joule's mechanical equivalent of heat by (J) we would have

$$\text{Heat in calories} = \frac{C^2RT}{J}$$

$$J = 4.2 \times 10^7 \text{ ergs.}$$

Magnetic Circuits.—

$$\text{Flux } (\Phi) = \frac{\text{Magnetomotive force } (\mathbf{F})}{\text{Reluctance } (\mathbf{R})},$$

$$\text{Magnetomotive force } (\mathbf{F}) = \text{Flux } (\Phi) \times \text{Reluctance } (\mathbf{R}),$$

$$F = \frac{4\pi}{10} At, \quad \mathbf{R} = \frac{\text{length of path of flux}}{\text{area} \times \text{permeability}} = \frac{l}{S\mu},$$

$$\Phi = \frac{4\pi}{10} At \div \frac{l}{S\mu} = \frac{4\pi}{10} \frac{AtS\mu}{l},$$

$$\frac{\Phi}{S} = \text{Density } (\mathbf{B}) = \frac{4\pi}{10} \frac{At\mu}{l},$$

$$\mathbf{H} = \text{magnetizing force per unit length} = \frac{4\pi}{10} \frac{At}{l},$$

$$\mu = \frac{\mathbf{B}}{\mathbf{H}} = \frac{4\pi}{10} \frac{At\mu}{l} \div \frac{4\pi}{10} \frac{At}{l} = \text{permeability.}$$

Equations for E. M. F. of a Dynamo.

E is proportional to ΦNn

$E = \frac{2\Phi Nnp}{60 \times 10^8}$ where Φ = flux entering armature from one pole.

$\frac{N}{60}$ = no. revolutions per second.

n = no. of inductors in series on armature.

p = pairs of poles, being 1 for a bipolar machine.

$\frac{Np}{60}$ = no. of cycles per second.

Equations for a Motor.—

$C = \frac{E - e}{R}$, $\quad E = e + CR$, $\quad e = E = CR.$ in which,

E = E.M.F. at motor terminals.
e = counter E.M.F. of armature in *volts*.
C = current in armature in *ampères*.
C_f = current in fields of motor.
C_t = total current = $C + C_f$
$C_t \times E$ = power in *watts* delivered to motor.
$C_f \times E$ = power expended in fields.
$C \times E$ = power delivered to armature.
$C \times e$ = useful work expended in armature.
$\frac{C \times e}{C_t \times E}$ = commercial efficiency of machine.

The *torque* or turning effort of a motor depends upon the armature current, number of armature inductors and flux through the armature. It is independent of the speed.

Proof $$HP = \frac{2\pi LFN}{33\,000} = \frac{eC}{746}$$

F = force exerted at radius L.
$\therefore FL$ = turning moment or torque.
e = counter E.M.F. of armature.

$$e = \frac{2\Phi Nnp}{60 \times 10^8}$$

$$\therefore \frac{2\pi LFN}{33\,000} = \frac{2\Phi NnpC}{746}$$

$$\text{Torque} = LF = \frac{2\Phi NnpC}{2\pi N\,746}\,33\,000$$

$$T = \Phi nCK$$

TABLE OF EQUIVALENTS.*

REDUCTION TO AND FROM C. G. S. UNITS.

In the column headed "Reciprocals" the numbers are the factors for reducing from C. G. S. to English values.

Length.

	Cm.	Reciprocals.
1 inch =	2.54	.3937
1 foot =	30.48	.032809
1 mile =	160 933.	6.2138×10^{-6}

Area.

	Sq. cms.	
1 sq. inch =	6.4515	.1550
1 sq. foot =	929.01	.001076
1 sq. mile =	2.59×10^{10}	3.861×10^{-11}

Volume.

	Cu. cms.	
1 cu. inch =	16.387	.06102
1 cu. foot =	28 316.	3.532×10^{-5}
1 gallon =	4 541.	.0002202

Mass.

	Gram.	
1 grain	= .064799	15.432
1 ounce Avoirdupois	= 28.3495	.035274
1 pound	= 453.59	.0022046

Velocity.

	Cms. per Second.	
1 foot per sec.	= 30.48	.032809
1 mile per hour	= 44.704	.022369
1 kilometer per hour	= 27.777	.036

Density.

	Gm. per cu. cm.	
1 grain per cu. inch =	.00395438	252.88
1 pound per cu. foot =	.016019	62.426

The value of g is assumed to be equal to 981.

Force.

	Gm.	Dynes.
1 poundal =	14.09	13 825.
1 pound =	453.59	4.45×10^5
1 grain =	.064799	63.6
1 kilogram =	10^3	9.81×10^5

Stress.

	Gm. per sq. cm.	Dynes per sq. cm.
1 lb per sq. foot =	.48826	479.
1 lb per sq. inch =	70.31	69 000.
1 ton† per sq. inch =	1.406×10^5	1.380×10^8

Work and Energy.

	Gm—cms.	Ergs.
1 foot pound =	13 825.	1.3562×10^7
1 foot poundal =	4.3×10^2	4.2139×10^5
1 kilogrammeter =	10^5	9.81×10^7
1 Joule =	1.109×10^4	10^7 :

Rate of Working.

	Gm—cms. per sec.	Ergs per. sec.
1 horse power =	7.604×10^6	7.46×10^9
1 force-de-cheval =	7.5×10^6	7.36×10^9
1 kilowatt =	1.019×10^7	10^{10}
1 watt =	1.019×10^4	10^7

(1 *horse power* = *746. watts*).

Mechanical Equivalent of Heat.

	Gm. cms.	Ergs.
1 gm. through 1°C. =	4.281×10^4	4.2×10^7
1 pound " 1°C. =	1.942×10^7	1.905×10^{10}
1 " " 1°F. =	1.079×10^7	1.058×10^{10}

(*1 gm. through 1°C.* = *1 Calorie* = *4.2 Joules.*)

* Everett C. G. S. System of Units

† 2000 lbs.

9. Schedule of Experiments.

1. Measurement of the "fall of potential" along an electrical conductor.

2. Measurement of the resistance of a conductor by the "fall of potential" or "drop" method.

3. Effect of temperature variation upon the resistance of metallic conductors.

4. Part 1—Measurement of the resistance of the armature of a dynamo or motor by the "drop" method and by comparison with a standard resistance. Part 2—Measurement of the field resistance of a dynamo or motor by means of a Wheatstone Bridge.

5. Part 1—Operation of a shunt wound constant potential dynamo. Part 2—Determination of the magnetization or saturation curve of a shunt dynamo. Part 3. Determination of the "building up" curve of a shunt dynamo. Part 4. Determination of the external characteristic or "working" curve of a shunt dynamo.

6. Operation of a compound dynamo and determination of the compound characteristic or "working curve."

7. Operation of a Thomson-Houston constant current arc dynamo and the operation and study of arc lamps.

8. Operation of a constant potential shunt-wound motor and the test for its commercial efficiency by means of the Prony brake.

9. Operation of a constant potential series wound motor (railway motor) and commercial efficiency test using the Prony brake.

10. Test for the commercial efficiency of a dynamo or motor by the "stray power" method.

10. Experiment 1.—"Fall of Potential" along an Electrical Conductor.

This experiment is intended to show the fact that when a current of electricity flows through any metallic conductor, there is a loss of electrical potential along the conductor. This loss is proportional to the strength of the current and to the length of the conductor, assuming it to be of uniform size and conductivity throughout its length.

The resistance of a conductor varies directly as its length, and inversely as its area and conductivity $R \propto \frac{l}{Sy}$. If the area and conductivity remain constant under any given conditions, the resis-

tance will vary directly as the length. By Ohm's law $E = CR$. ∴. If the current in a conductor remains constant, the difference of potential along the wire will vary directly as the length. Over equal lengths of conductor there will be equal differences of potential and if twice the length of conductor is included between the voltmeter terminals, the voltmeter will give a reading twice as large as before.

Method.—In order to prove this, a current may be passed through a conductor and by means of a voltmeter the differences of potential between points along the wire at uniform distances apart can be measured. Record these distances and the corresponding voltmeter readings. Also note whether the sum of all the readings equals the total "drop" as measured between the ends of the conductor. An ammeter should be inserted in the circuit, as shown in the diagram, in order that the current strength may be kept constant throughout the experiment.

After taking this set of readings one terminal of the voltmeter may be fastened to the conductor at about its middle point and the other terminal to the conductor at one end. Note the readings of the voltmeter as the current is increased by decreasing the variable resistance at (VR).

Connections are as shown in Fig. 1 in which (x, y) is the conductor; (VR) is the variable resistance used to regulate the cur-

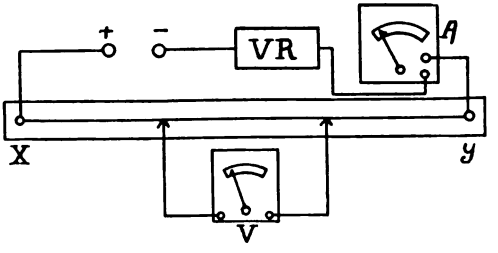


FIG. 1.

rent; (V) is the voltmeter to measure the fall of potential; (A) is the ammeter to measure the current, and ($+, -$) is the source of power.

Report.—The report of this experiment should contain two curves on the same sheet, one showing the relation between voltmeter readings and lengths of conductor, the other showing the relation between voltmeter and ammeter readings; voltmeter

readings to be plotted as ordinates, the other readings as abscissas.

Note.—In the above experiment as well as in many subsequent ones, it is necessary to insert in the circuit containing the instruments and apparatus under test an extra resistance of large carrying capacity and usually of high resistance in order to control the strength of the current as derived from the main switchboard. For this purpose there may be used adjustable resistances known as *water rheostats* in the shape of barrels containing water and with movable electrodes. When it is desired to *increase* the current strength, the electrodes are moved *nearer* to each other, while, when it is necessary to *decrease* the strength of the current, the electrodes are moved *farther* apart.

11. Experiment 2.—Measurement of the Resistance of a Conductor by the "Fall of Potential" or "Drop" Method.

The "fall of potential" or "drop" method of measuring the resistance of a conductor is identical with the foregoing experiment. A known current is passed through the conductor whose resistance is required and by means of a voltmeter the difference of potential between the ends of the conductor is measured. Then the resistance may be calculated by Ohm's law in the form

$$R = \frac{E}{C}.$$

Method.—In this manner the resistance of 8 B. & S. copper wire can be determined, using different values of current at intervals of 5 ampères from 0 to 25 ampères. The low reading scale of a Weston voltmeter can be used for the measurement of the "drop" between the ends of the wire. Any change in resistance due to change in temperature should be noted.

Report.—The report should contain curves showing the relation between current readings and the values of the corresponding "drops"; also between current readings and the values of the resistance as calculated by Ohm's law. Use the values of the current for abscissas and the others for ordinates. The connections are the same as in Fig. 1.

Also determine the current, cold and hot resistance, total watts and watts per candle power for a 16- and a 32-candle power 115-volt lamp.

12. Experiment 3.—Effect of Temperature Variation upon the Resistance of Metallic Conductors.

Electrical energy may be employed to do work of various kinds such as magnetic, mechanical, chemical and thermal. In doing any of these, part of the energy is wasted so far as any useful purpose is concerned, this following from the fact that conversion of energy from one form to another cannot take place without some waste of energy. This energy which is wasted is converted into heat and is transferred to other bodies by radiation, conduction and convection.

When electrical energy is transmitted through a conductor, resistance is offered to its passage, this resistance depending directly upon the length and inversely as the area and conductivity of the material. The result is that a certain amount of energy is used in forcing the current over the resistance and this energy develops heat in the conductor. When this resistance is high and a large amount of current has to be transmitted along the wire the loss is large and *vice versa*.

If the length and cross section of two conductors of different materials are the same, the heat developed will depend entirely upon the specific resistance of the materials. As the specific resistance of copper is lower than that of all metals except silver, and its price is not prohibitive, this metal has become to be the recognized material for use in electrical apparatus. Iron has about 0.16 and German silver about .06 the conductivity of copper.

Joule found by experiment that the number of heat units developed in an electrical conductor is proportional to the resistance, to the square of the current and to the time of passage of the current. Joule's law can be expressed as follows:

Heat in calories $= c^2 R T \times 0.24$.

$T =$ time in seconds.

As the resistance of metallic conductors increases with rise in temperature, the temperature of a conductor and the amount of energy dissipated by it will increase until its rate of loss of heat by conduction, convection and radiation is balanced by the rate at which heat is developed due to the passage of the current.

The resistance of copper changes with variation in temperature, the relation being represented approximately as follows:

$$R_t = R_t[1 + .004(t_1 - t)].$$

R_t = resistance when hot.
R_t = resistance before passage of current.
t_1 = temperature °C. when hot.
t = temperature °C. before passage of current.

Another manner of expressing this is that copper has a positive temperature coefficient of 0.4% per degree Centigrade.

Iron and other pure metals have approximately the same temperature coefficient as is given for copper.

German silver may possess a temperature coefficient as small as 0.04% per degree Centigrade, which enables it to be used in making standard resistances and coils, since its resistance remains practically constant.

Method.—Connect in series some copper, iron and German silver conductors. Pass through these and a suitable variable resistance and ammeter, currents of *increasing* strengths, measuring the "drops" across the terminals of each material for corresponding values of the current. Allow the temperature of the conductors to reach a stationary value after each change in the current and *before* making a set of readings. This condition can be ascertained by connecting the terminals of the voltmeter to the iron resistance and noting when the pointer arrives at a condition of rest. This will indicate that the resistance of the iron is no longer altering in value and, therefore, the material has arrived at its final temperature. If this precaution is not taken, the curves showing the effect of temperature on the resistance will not properly represent the gradual and uniform change.

Report.—The report should contain curves illustrating the relations between the current values in ampères, plotted as abscissas, and the calculated resistances of each material as ordinates. Also curves between current values in ampères, as abscissas, and watts expended in heating each material, as ordinates.

13. Experiment 4.—Part 1—Measurement of the Resistance of the Armature of a Dynamo or Motor by the "drop" method and by Comparison with a Standard Resistance.

Owing to the comparatively low resistance of armatures it is generally impossible to obtain satisfactory results in the measurement of their resistances by the use of an ordinary Wheatstone bridge and a galvanometer. The armature resistance is made low

in order that the energy wasted in this part of a dynamo or motor may be as small as is consistent with the size and design of the machine. Moreover it is necessary that the resistance of the armature be low, in order to obtain good inherent regulation of potential in a dynamo and speed in a motor.

The resistance of an armature circuit is composed of the resistance of the conductors themselves, the brush contacts, that is the resistance of the surface contact between the copper or carbon brushes and the commutator (in the case of carbon brushes this may amount to an appreciable value), and the leads or cables from the machine terminals to the brush holder studs. This last is usually of small amount.

Methods.—There are two convenient and accurate methods for the determination of such low resistances, one of these employing the measurement of current and potential, the other of potential only. Calibrated standard commercial instruments are of sufficient accuracy for these measurements.

First.—Pass through a circuit containing the armature, an ammeter and a variable resistance, a current which will produce a sensible "drop" or difference of potential across the different parts of the armature circuit. These "drops" can then be measured by means of a low reading voltmeter, whose terminals can be transferred from one part of the circuit to another. The deflections on both instruments should be large in order to secure accuracy in the results. The resistance of any part can be calculated by Ohm's law, the current and E. M. F. being known.

By this method the resistance of the *armature leads*, *brush contacts* and *armature* itself can be determined, it being advisable to take a number of sets of readings with different values of the current in order to eliminate errors and variations.

It will be found in the case of machines with carbon brushes, that the brush contact resistance varies with the variation in the current used, being lower for the larger values of the current. Nothing of an absolutely definite nature regarding this resistance can be obtained in this manner, but some idea can be had of the importance of this resistance in dynamo and motor designing and testing.

In case the E.M.F. of the current supply is so high that too large a current would be sent over the resistance of the armature circuit, if connected directly to this E.M.F., it will be necessary

to insert a variable resistance to regulate the strength of the current to the proper value for the machine under test. Do not allow the armature to rotate when the measurements are being made, for a counter E.M.F. is generated, which decreases the current and causes an apparent increase in the resistance of the armature. If the armature is permitted to run in this way and without any field, it will tend to rise to a dangerous speed.

Second.—In this method there is employed a *known resistance* of large current carrying capacity and possessing a low temperature coefficient. This latter quality insures a constant resistance with a varying temperature of the material. This standard is placed in series with the armature circuit and a controlling rheostat. A current of suitable strength is passed through the circuit (it is not necessary to measure this current) and the drops of potential across the armature, brush contacts and armature cables, and the standard resistance are recorded. The ratio of these "drops" will be equal to the ratio of the two resistances, or

$$E' : E = R' : R \qquad \text{or}$$

$$R' = \frac{E' \times R}{E}$$

E' = drop across the unknown resistance (armature, etc.).

E = drop across the standard resistance.

R' = value of unknown resistance (armature, etc.).

R = known resistance of standard.

This method possesses the advantage of requiring only one measuring instrument with all readings of the same order. The resistance of the standard being once known and not liable to alteration removes one possibility of error. In the first method an ammeter would have to be calibrated or tested for every important measurement. In Fig. 2 is given a diagram of connections, the standard resistance being substituted for the ammeter in the second method

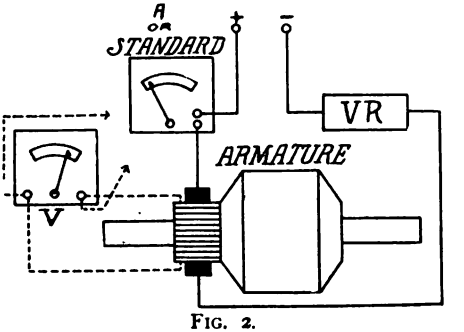


FIG. 2.

14. Experiment 4 —Part 2—Measurement of High Resistance, Such as a Field Coil of a Dynamo or Motor by the use of a Wheatstone Bridge.

Wheatstone's bridge, or balance is an arrangement of resistances, typically represented in Fig. 3. *a* and *b* are two sets of coils, usually in the ratio 1 : 10 : 100 : 1000.

Suitable plugs permit the use of any coil at pleasure.

R is a set of coils, usually running from 1 to 10 000 ohms, so arranged that any number of units from 1 to 10 000 may be introduced into the circuit.

X is the unknown resistance to be measured.

In using the apparatus, a battery is connected to the points (*B*, *B*), and a sensitive galvanometer to the points (*G*, *G*), as shown.

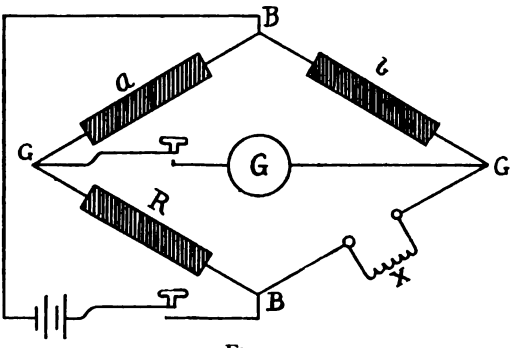


FIG. 3.

A key is usually included in the battery circuit and another in the galvanometer circuit. These keys normally stand open.

The unknown resistance being connected as shown, a coil in each of the sets *a* and *b*, either equal or having the ratio of 1 to 10, 100 or 1000 is unplugged. The resistance *R* is then adjusted until the galvanometer suffers no deflection upon depressing the battery and galvanometer keys.

It may be easily shown that when the above condition obtains, the following relation exists between the four resistances

$$\frac{a}{b} = \frac{R}{X}.$$

In Wheatstone bridge sets, as usually constructed, the resistances *a*, *b*, and *R*, consist of coils inclosed in a box and connected to

terminals on the cover. Binding posts on the cover serve for connecting the battery, the galvanometer, and the unknown resistance. These binding posts are generally marked *B*, *G*, and *X*, respectively, the battery, of course, being connected to *B*, the galvanometer to *G*, and the unknown resistance to *X*. Sometimes the galvanometer is included in the set and is permanently connected inside the box.

Method.—To measure the resistance of a field coil, connect it to the posts marked *X*. Connect a battery of, say, three dry cells to the posts *B*, and a suitable galvanometer to the posts *G*, if the galvanometer is not already connected inside the box. Now, if there is nothing to indicate the value of the resistance to be measured, begin by unplugging equal resistance in *a* and *b*, say 100 ohms; then unplug any coil in *R*, depress the battery and then the galvanometer key, holding both down and note the direction in which the pointer moves. Now change *R*, making it much larger or smaller until a deflection in the opposite direction is obtained. The true value of *X* will then be somewhere between this first value and the last value of *R*.

Now beginning with a value that is known to be too large, vary the resistance in *R* systematically, trying each coil in succession until one is found that is too small. Leaving this in circuit, try the smaller resistances in order, until a balance has been nearly obtained. Record this value of *R*.

If *X* proves to be a small resistance, its value should be determined to a fraction of an ohm; for this purpose, change the resistances in *a* and *b*, making *a* 10 times *b*; then obtain a new balance, beginning by making *R* 10 times as great as was required for the balance with *a* and *b* equal. Repeat, making *a* 100 times *b*.

Precautions.—If the galvanometer is of the magnetic needle type, it must be kept at some distance—several feet—from the field which is being measured; otherwise the needle will be deflected by the magnetism of the field.

It must be rembered that in consequence of self induction, the current in the field coil does not immediately reach its full strength upon closing the battery key. In other words, when the current begins in the coil, it is opposed by the self induction as well as by the true resistance, and the coil has an *apparent* resistance much greater than the true resistance. The true balance can only be

obtained, therefore, by giving time after closing the battery key, for the current in the coil to become steady before closing the galvanometer key. This may require several seconds or, in large machines, even a minute. To avoid waiting, it is best when the balance is nearly reached to keep the battery key closed while changing *R*.

Having obtained a balance, try to determine approximately the time required for the current in the field to become steady, by closing the galvanometer key at different intervals after closing the battery key.

15. Experiment 5.—Part 1.—Operation of a Shunt Wound Constant Potential Dynamo.

Before making any experiments with a dynamo, its component parts should be carefully inspected in order not only to become familiar with their construction but also to observe any defects which may exist.

The specific points to be noted under the head of defects are as follows:

(*a*) Whether or not there is sufficient oil in the bearings or cups.

(*b*) Condition of the brushes and commutator: the brushes should be put in proper condition if they are badly worn or incorrectly set, and if necessary, the commutator should be smoothed off with fine sand paper (not emery).

(*c*) Tension of springs on brush holders, these being given proper amount of tension.

(*d*) Ease of turning of armature, this being ascertained by rotating it with the hand, in the case of small machines, or by a lever in the case of large ones.

(*e*) Correctness of the connections for the particular type under investigation.

Some of the causes which prevent a dynamo from "building up" its field magnetism or exciting its field are added in order that if any of these troubles are met with they can be recognized and remedied.

If a dynamo fails to "excite," it may be due to one or more of the following causes:

(*A*) Residual magnetism is weak or not present.

(*B*) Reversed field connections, causing whatever E.M.F. is generated to send current the wrong way through the field coils and thus weaken the residual magnetism instead of strengthening it.

(*C*) Short circuit, either in the machine or in the external circuit

(*D*) Field coils opposed to each other, each tending to "build up" the field in the opposite direction.

(*E*) Open circuit in field coils or connections.

(*F*) The brushes may not be in the proper position on the commutator.

(*G*) Rheostat in the field circuit of too great resistance, thereby preventing sufficient current from passing through the field coils.

Method.—Before operating a dynamo, make the following determinations, the resistances being the cold resistances :

1. Resistance of the field coils, using a Wheatstone bridge.

2. The resistance of the armature circuit and its parts by fall of potential, using sufficient current to give a large deflection on the instruments.

3. After these determinations have been satisfactorily made, the machine can be run as a dynamo, and a load, such as lamps or any other convenient translating device connected to the machine. Before starting the dynamo, make the connections as shown in Fig. 4, inserting an ammeter in the external circuit and placing a voltmeter across the *terminals* of the machine.

In starting, precaution should be taken to have the maximum resistance of the rheostat in series with the field coils, otherwise the machine may build up too rapidly and possibly to too high a voltage, thus burning out or otherwise endangering the lamps and apparatus connected to the terminals of the dynamo. In order to increase the E.M.F. of the machine this field resistance is gradually *decreased* until the potential of the machine has attained its proper value. When this has occurred, there should still be left in the rheostat some resistance which will allow for regulation of the E.M.F. when the load on the machine is increased and the E.M.F. tends to fall.

When the potential, as indicated by the voltmeter, is of the proper value for the particular dynamo under test, connect a portion of the load, gradually increasing it until full load is attained. Note the effect of this action on the potential at the terminals. *Explain* this result and ascertain the method of *compensating* for it.

4. With dynamo running at constant speed and steady load, shift the brushes a short distance around the commutator by means of the rocker arm handle. *Note and explain the results.*

5. Note, by feeling with the hand, the rise of temperature of the

commutator, armature, bearings, and field coils after running for some time at full load.

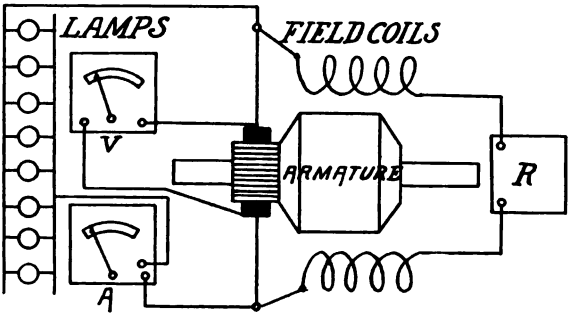


FIG. 4.

The connections of a shunt-wound dynamo are as shown in Fig. 4.

16. Experiment 5.—Part 2.—Determination of the Magnetization or Satura ion Curve of a Shunt Dynamo.

The *magnetization* or *saturation* curve of a dynamo shows the magnetic condition of the magnetic circuits as a whole from zero to full magnetization. The magnetization is produced by the ampère-turns of the field windings, these being the product of the number of turns in the field coils and the current in them. This magneto-motive force acting over the reluctance of the magnetic paths produces a magnetic flux. The E M.F. of a dynamo is generated by continuously varying this flux through the armature coils, by rotating the coils with respect to this flux. The materials used in magnetic circuits possess the physical property of becoming magnetically saturated; that is, when the density of the flux becomes so great that it is difficult to increase it without greatly increasing the M.M.F. the material is said to have reached saturation. If this were not so, the magnetic flux might go on increasing directly with the M.M.F. While the primary purpose of the saturation curve is to indicate the magnetic condition of the magnetic paths as a whole, there will also be shown that part of the curve upon which the machine should be operated to give the best regulation of E.M.F.

The M.M.F. $= \frac{4\pi}{10} At$ and as $\frac{4\pi}{10} t$ is a constant, the M.M.F. can be expressed by the values of the current in the fields.

The E.M.F of a dynamo armature $= \frac{2\Phi Nnp}{60 \times 10^8}$ and as all but the flux Φ is a constant with a constant speed, the E.M.F. is a measure of the flux values.

Therefore the magnetization curve can be expressed between the corresponding values of the field current and the E.M.F.'s at the armature terminals.

Method.—The armature of the machine under test can be run at its rated speed, which should be recorded; currents, obtained from a suitable source of power, and ranging in value from zero to the full rated capacity of the fieldcurrent can be passed through the field coils and the corresponding armature E.M.F.'s recorded. If there should be any variation in speed during the test a proportional correction of the E.M.F. should be made. As the field currents in field circuits are usually small, a low reading ammeter is essential. In order to vary the current through the wide limits required, it is necessary to employ a high variable resistance in series with the field, this resistance possessing a sufficient number of steps to give small variations in the current values. This presupposes that the field is excited from some source of power of nearly the same E.M.F. as the machine under test. This large variable resistance is not always available and to avoid its use a second method is given, as follows:

Between an E.M.F. of about the same value as that of the machine under test, place a resistance, such as a long length of German silver

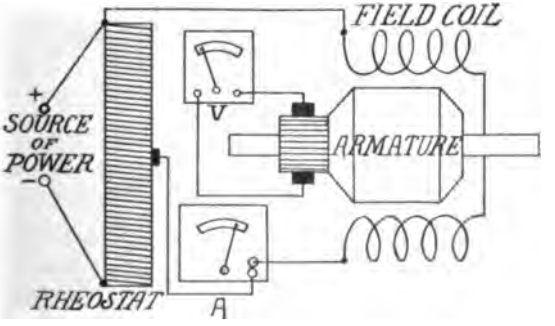


FIG. 5.

or iron wire or a rheostat with many points. Between one end of this resistance and a movable point upon this wire, differences of

potential will exist when current passes along the wire. These can be applied to the shunt field of the dynamo by connecting one end of the resistance and the movable point to the windings, as shown in Fig. 5, which shows the connections for this test. By using this method very accurate adjustments of the field current can be effected.

In determining the magnetization curve, always bring the magnetizing current *up to* the value at which it is desired to read; do not carry it above this point and then reduce it. The reason for this is, that a higher point is obtained on the curve if the current is brought *down* to the proper reading than when it is brought *up* to the same value.

The higher point is that one which would be obtained on what is known as the descending magnetization curve, this curve being obtained by reducing the field currents from the full value attained. These two curves will be slightly separated owing to *hysteresis* or the magnetic retentiveness of the materials, the descending curve giving the higher values for E.M.F.'s with equal M.M.F.'s.

17. Experiment 5.—Part 3—Determination of the "building up" curve of a Shunt Dynamo.

The "building up" curve shows the relation which exists between the M.M.F. or *At* of the field windings and the flux through the armature, the armature exciting its own field, thus operating as a self-excited machine. The values are expressed as in the magnetization curve.

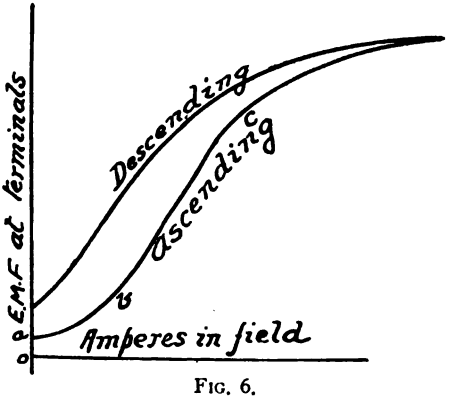


FIG. 6.

This curve, illustrated in Fig. 6, shows the manner in which

every shunt dynamo builds up its E.M.F. At any rated speed the resistance of the field circuit must be reduced to a value where the E.M.F. as at *a*, due to residual magnetism in the fields, will send sufficient current through the field circuit to increase the flux and E.M.F. When this increase commences, as at *b*, Fig. 6, the rise in E.M.F. takes place rapidly and without any further change in the resistance of the field circuit. This point is known as the "critical resistance" for building up, and any value above this will prevent the E.M.F. from increasing. The machine is operating as a series dynamo and has the same characteristics as that type of machine.

The E.M.F. will increase until the magnetic circuit has become well saturated. As no increase in M.M.F. can occur without increase in E.M.F., the field resistance remaining fixed, the E.M.F. will eventually remain stationary. Note the value of this "critical resistance" for existing conditions.

Method.—Connect the machine to be tested, as shown in Fig. 7, and record the corresponding values of the field current and E.M.F.'s for increasing and decreasing values of the field currents. The difference as shown by the curves in Fig. 6 is due, as in the magnetization curve, to hysteresis or magnetic lag.

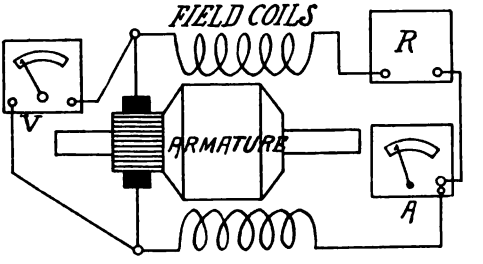


FIG. 7.

18. Experiment 5. Part 4—Determination of the external characteristic or "working" curve of a Shunt Dynamo.

The *External characteristic* or "working" curve of the shunt dynamo shows the effect of the increase of armature current upon its terminal E.M.F., where no attempt is made to regulate the potential of the machine. It is a measure of the inherent regulation of the machine for constant potential. If the armature resistance is large the regulation will be poor and *vice versa.*

If a shunt dynamo should be self-excited to its rated E.M.F. and

the current through its armature gradually increased by adding lamps or otherwise decreasing the external resistance, the E.M.F. at the armature *terminals* would gradually decrease, due to *CR* loss in armature, armature reaction and decrease in field current. When the field current becomes so decreased that any further small decrease widely changes the E.M.F., both this and the current rapidly decrease, eventually falling to nearly zero, and taking the form shown in Fig. 8. In the event of a shunt dynamo being

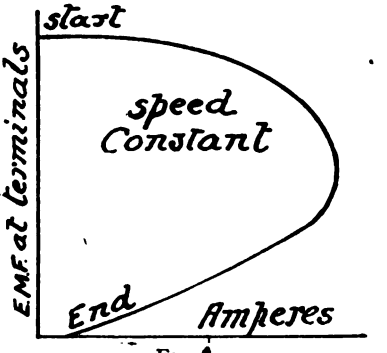


FIG. 8.

short-circuited, this is the action which takes place but accompanied by violent sparking and mechanical strain.

Method.—Operate the machine as a shunt dynamo with connections as shown in Fig. 4 placing an ammeter in the field circuit. The sum of this current and that in the external circuit will be the total current delivered by the armature. The speed should be constant. Readings should be taken of the total current, E.M.F. at terminals and speed. The machine should be brought up to its rated E.M.F. and then the field resistance left fixed.

External currents should then be increased until the machine fails to generate. The result will be similar to the curve in Fig. 8.

THE PROGRESS IN ORE DRESSING*—II.

BY H. C. BLÖMKE.

(Continued from page 48, Vol. XXI.)

2. Principles and methods of ore dressing as employed in the newer mills.

The old principle, to sort out as completely as possible, the best pieces and the ore rich enough for immediate smelting from the mine product, before submitting to crushing, and then crushing gradually, is also employed in the newer mills as will be seen from the following:

A. HANDPICKING OR DRY DRESSING.

Even though dry dressing has long since been simplified by the application of the rock crusher to the mixed pieces of gangue and mineral, and large complex pieces of ore about 60 mm. size, the present system of Lührig is still simpler and more economical, and not wasteful in mineral. Lührig has adopted the following plan for ore containing galena, blende, some chalcopyrite, and pyrite, with quartz, or calcite and country rock as gangue, hence a rather difficult ore to dress.

The large mixed pieces of ore and gangue are separated under ground from the mine fines, and are picked over into rich clean pieces of mineral, rich complex pieces, and waste, while some ore, too complex for hand sorting, goes to the crusher direct (50–60 mm. size), and is not hand picked as it was in some of the older mills.

The mine fines are dumped over a grizzley, whose bars are placed 50–60 mm. apart, when ore has common gangue rock, but only 30 mm. apart when the gangue rock is slate, so that the long narrow pieces of slate will not go through but can directly be kept out for the waste dump.

The coarse material, passing over the grizzley, goes to a picking table placed at the foot of the grizzley, and undergoes a more careful picking than in the mine or at the shaft. This picking table requires an extra meter in height in the construction of the mill, but is of good use as the material can be scattered better, and thus sorted more thoroughly by the men.

* Translated by Charles Fulton from the "Berg und Hütten mannisches Jahrbuch."

The grizzleys are best constructed of parallel, movable iron bars; those with square openings are not so good and should only be used where a considerable amount of slate occurs.

The complex ore which cannot be further separated is conveyed directly to the crushers, in smaller works, while in larger mills it goes to storage bins, and from there continuously to the crushers and thence to wet dressing.

The ore produced by the cobbing and picking, and which is to be crushed, also goes to bins, and here begins the division into the two parts of a large galena and blende dressing works, one part for the galena ores, and the other for the blende ores. The mine fines separated by the grizzleys are also caught in bins. Out of these bins which have considerable capacity the ore is transported to the nearby mill, the different varieties going again to bins there, in connection with the four rock crushers. Between these last bins and the crushers there are shaking screens to take out the fine material from the mine fines, and also the fines produced by the cobbing, which are not to pass through the crushers.

These shaking screens have round openings, 40 to 60 mm. in diameter allowing pieces of this size to pass through, which, after passing the preliminary trommels, reach a rotating picking table, where further sorting is done. The crushers also crush to 50–60 mm. in size.

At the dressing works of the "Gute Hoffnung" mine described in part I., where considerable pyrite occurs with the blende and galena, from the former of which, as is well known, it is almost impossible to separate the pyrites automatically, Lührig's system of separating and cobbing has accomplished good results.

At the dressing works at Laurenburg, also described in part I. of this paper, Lührig has still further simplified the hand dressing. He has here, even though there is considerable siderite present, replaced the picking out of pieces of ore and gangue by a giant rock crusher.

This crusher has a crushing opening of 75–80 mm. wide, and the bumping screen between the crusher and the picking table has a space opening of 25 mm. as already mentioned. The coarse ore passing over the screen goes to the picking table, where but seven boys are employed. These pick out blende and galena ores, complex ores, siderite, chalcopyrite and waste. The further separations by hand also require but little labor. The dry dressing re-

quires less men now than it did formerly, only 11 against 40 employed by the old method, with a total capacity of the works of 150 to 200 tons per shift of 10 hours.

This method works so well, that it can also be recommended for the dressing of much more difficult ores.

The amount of picked smelting ore has not been diminished by the new method. A comparison of results for two months of the total blende production shows 8.5 per cent. piece smelting ore, against 8.2 per cent. by the old method. Coarse concentrates show 14.1 per cent. against 6.4 per cent. by the old method. This shows that there is no increased loss of mineral by the use of crushing machinery for work formerly done by hand. The large stone crusher does its work more evenly, without making an undue amount of fines, than could be done by hand with heavy hammers. The picking on the large rotating picking table is more completely and carefully done than on a picking bench.

The extensive separation by hand, in use formerly at Laurenburg (No. 15. d. B. & H. Zeib., 1882), and Himmelfahrt, etc., and still in use at Ems (No. 30, 35 and 36 d. B. u. H. Zeit., 1882) Friederichsegen, etc., where up to 20 different classes are made, is considerably more costly and at the same time not more complete.

With the great drop in the prices of metals during the last few years, it is essential to dress the ore cheaply, and it is especially the separation by hand which runs up the cost of dressing. C. Lührig, with his rough sorting and picking, has undoubtedly introduced a great improvement in ore dressing, in that with the lower costs the clean ores are not crushed into medium and fine sizes as before, as the foregoing and following results prove.

With the ordinary hand dressing, the amount of work done by the pickers is very small, especially where many classes are made; hence dressing of this kind is applicable only to precious or valuable ores; for lead, zinc and copper ores, considering the present low price of metals, the Lührig system only is to be recommended, even though siderite, pyrites or barite is present in the ore.

For the medium class of precious ores the rock crush ercan also be used to advantage, as has been demonstrated recently at Freiberg, at the Central dressing works of the Himmelfahrt mine. In the new separating works at the David shaft of this mine, a rock crusher has been installed directly actuated by steam for the rough crushing of the coarser ore which is to be sorted.

Further, the Sachsiches Yahrbuch, 1892, states "that the method of dressing was improved at the Alte Hoffnung, Gottes Ebrstollen, by installing a rock crusher run by compressed air."

The new method can be considered as the model to be followed, since it has proved efficient under difficult circumstances such as exist at Werlau St. Goar, and at Laurenburg; but where sufficient grade or drop is available, it is best to cob the coarse above 50 mm. size which goes over the grizzley on a moving table; also it is best to treat the material above 14 mm., say 20 to 30 mm., from the mine fines, and the crushing ore, on separate picking tables.

The careful sorting out of pieces over 50 mm. each on a separate picking table is rational, since, beside the clean ore and waste rock, those harmful minerals are sorted out, which make the wet dressing more difficult. This is not possible to the same extent in the ordinary way of sorting. Pieces from which, clear rich ore, mixed mineral, and stamp ore can be separated, reach a table near by and are subjected to cobbing.

Engineer Gröppel has still further improved Lührigs coarse separation, as at Grube Weiss at Bensberg near Ramsbeck, and at Selbeck near Dusseldorf. He made his grizzleys with a space of 180 mm. between bars. Out of the pieces over 180 mm. only the easily seen clean ore and waste rock are taken, while the rest goes into the bins or storage hopper under the grizzleys, which contain the ore of less than 180 mm. From the storage hopper the ore is discharged by means of an automatic distributor into a large washing and classifying trommel, strongly made of iron plate. This cleans the mineral, and, by means of one or two screens at the end, with 80 mm. and 25 mm. holes respectively, sizes the ore into sizes of 80–180 mm., and 25 to 80 mm. and mine fines under 80, respectively, to 25 mm. It also serves as a distributor, and does this work very uniformly. This is one of the greatest improvements in ore dressing which has been made within the last ten years, since it regulates the work of the whole dressing mill. The pieces of over 80 mm. and respectively over 25 mm. fall from the trommel, cleanly washed, on either a single or double moving belt, where the cobbing and sorting takes place. This can here be done very carefully, since the mineral on the belt is in a thin layer, due to the automatic constant, feed enabling the pickers to do more and better work, thus saving considerable labor. The following products are

picked out: clean ore—complex ore, and waste rock, the ore containing finely disseminated mineral being carried by the belt into the rock crusher (size 80–180 mm.), and into the coarse rolls (size 25–80 mm).

This arrangement is to be preferred to that of Lührig at Laurenburg, because the clean ore and waste rock can be retained more completely, and the dressing ore is distributed and fed more evenly to the mill. The dry and wet dressing have practically become one by this arrangement of Gröppel's.

The amount of clean smelting ore, resulting from the dry dressing and picking at one of the above mentioned mines was as follows:

	Per cent. of the total production.
a. By the old method	41.1 per cent., Galena.
b. In the works built by Lührig . . .	45–46 per cent., Galena.
c. By the old method	9.8 per cent., Zinc Blende.
d. In the works built by Lührig . . .	25–26 per cent., " "

Concentrates.

a. By the old method	17.9 per cent., Galena.
b. In the works built by Lührig . . .	13–14 per cent., "
c. By the old method	27.3 per cent., "
d. In the works built by Lührig . . .	20–21.5 per cent., Galena.

Clean ores and Concentrates.

Adding $a + a$ by the old method . .	64 per cent., Lead Ores.
" $b + b$ in the works built by Lührig	58–60 per cent., Blende.
" $c + c$ by the old method . .	37.2 per cent., Blende.
" $d + d$ in the works built by Lührig	46–48 per cent., "

The ore dressed in the new mill was poorer than that dressed in the old works; that more smelting zinc ore was taken out by the new method in spite of this is founded, in my opinion, upon the fact that the rock crusher makes less fines, and that better picking and sorting can be done upon the movable picking tables than in the ordinary way of sorting and picking.

These figures prove what was said in the foregoing concerning the simplified method of dry dressing. A different method, separating certain minerals, in a dry way, by machinery, has been in-

troduced by Mr. Bieher, of Hamburg, by means of his, "dry separator" in combination with crushing and sieve arrangements. This method or system, known under the name of "Pape Henneberg" (See No. 34 d. Zeitschr. d. V. d. Eng., 1893. The Eng. & Min. Jour., No. 20, 1894. Oesterr. Zeitschr., No. 42, 1893, and No. 6, 1894, B. & H. Zeit., 1893, p. 190 and 1895, p. 31 and Nos. 32 and 28, 1896), which is designed mainly for gold ore and similar precious ores, as well as other finely disseminated ores, consists mainly in liberating the values by fine dry crushing, in the concentration and separation by means of centrifugal apparatus, and in the sizing of the grains gained by the last named apparatus.

The minerals to be separated must be of different hardness, or the valuable mineral, *i. e.*, gold, must be finely disseminated in quartz or similar gangue. In the "dry separator" the mineral is freed from dust by an exhauster, and then classified according to *specific gravity* into various sizes by letting the centrifugal force act over circular basins. Then, by simple sizing of the separate classes, a portion of the ore is obtained which is of smaller size than the barren or waste gangue. The middle products and the dust or fines must be dressed in the wet way on tables.

This method has been, considerably improved by Engineer Pape, as concerns the separation, by means of a "Luft sichter."* This will be further discussed under separation.

The method of Buttgenbach, employed at one one time at Lintorf, near Dusseldorf, where blende occurs combined with much pyrites, has much in common with that of Bieher. Buttgenbach crushed blende and pyrites middle products in a Vapart centrifugal mill, by which the harder pyrites broke coarser than the more brittle blende, so that the latter could be separated from the pyrites more or less completely in a trommel.

B. Wet Dressing.

The Crushing of the Ores.—The method of crushing introduced into the Lührig Dressing Mills differs from that previously used in the following points.

In works of two systems of apparatus, as well as in smaller works of a single system of apparatus, the crushing of the ore is a gradual one, from the jaw crusher to the stamps. The jaw crushers

* Das comb, Gold extractions—Verf. Pape Henneberg, und Göppner Diehl. Oesterr. Zeitschr., No. 23, 1897, u. B. & H. Z, No. 50, 1897.

break through a 30–60 mm. space according to the fineness of dissemination of the ore, and receive the ore of over 50–60 mm, size, from the sorting, picking and cobbing.

The product of this crusher (440x220 mm. jaw opening) of over 20–30 mm. size, in which the mineral is not sufficiently liberated, is sent from the cobbing table to the coarse rolls which crush to 10–12 mm. size. The coarse ore which does not break to this size by passing through the rolls, does not, as happens in other places, pass through these same rolls again, but goes from the trommel to the medium rolls. This crushes to about 6 mm. The over-product of the trommel belonging to the medium rolls, goes directly to the fine rolls, where it is crushed to about 4 mm. size. The coarse product over 4 mm. goes from the trommel to the stamps, by means of bucket elevators, where it is crushed finally to about 1½ mm. size.

The medium and fine rolls and the stamps also receive, aside from this, certain hutch work from the jigs, for further liberation of the ore by finer crushing.

In the rolls the improvement has been introduced of having the medium and fine rolls of the same diameter as the coarse rolls. In this way the cast steel jackets can be used on all the rolls of the mill, so that the jackets of the medium and fine rolls are fitted to the coarse rolls without being first turned down, and the jackets of the latter, after being turned down to even surface, can be used on the medium and fine rolls.

To facilitate the exchange and reduce repair costs, one or two pair of rolls with axles are held in reserve, so that the jackets need not be taken off the cylinders, and the latter from the axle.

The greater diameter of the medium and fine rolls has the further advantage, that such rolls have a greater capacity, and also, with the greater surface of contact of the jackets, a more complete liberation of the mineral is accomplished than with rolls of small diameter, in which the ore is often allowed to pass through without complete crushing, necessitating much repetition. The amount of wear is also smaller, due to larger surface contact. C. Lührig has installed rolls of 705 mm. diameter.

For the coarse rolls a diameter of 900 to 950 mm. is considered more advantageous. This diameter is used at Ems. This size can also be given to the medium and fine rolls, since then the work they do is still better and the wear of the jackets considerably

less. This has been demonstrated in the dressing mill already mentioned, the Grube Pauline, near Nassau. There are two rolls of 900 mm. diameter in use at this mine, one serving for the coarse crushing of grains of over 16 mm. size, and the other for the fine crushing of the jig hutch work (middles) of less than 16 mm. size. The cast steel jackets of the fine rolls were still good for work after 9 months use, and not worn unevenly, and this with a gangue and mineral quite hard.

With medium and fine rolls of 250–400 mm. diameter, of which many are still in use (at Clausthal 300 mm. at Ems 600 mm.), the cost of changing the jackets is considerable, because for fine crushing the jackets must be often changed and turned down.

Rolls of large diameter, however, cannot be placed on the bearers or girders of the building, on account of the great vibration, but must be located on the foundation or on special piers, as already mentioned.

Where small loss of mineral in the tailings is sought for, a fine roll of large diameter is not alone sufficient for the thorough liberation of finely disseminated mineral, and C. Lührig has applied the method of Clausthal in his dressing works, of stamping the *jig products?* of the fine jigs, with the difference, however, that only the poorest ores are stamped. In Clausthal a great deal more of the *jig products*, particularly of 3.5–7.5 mm. size, goes to the stamps, on account of the smaller number of sieves of the jigs. At Clausthal six times as many stamps are in use as at Ramsbeck (187 against 30), while but twice as much ore is treated at the first mentioned place. The ore contains about the same percentage of lead and zinc mineral at both places.

At Laurenburg, as in most German dressing works treating lead and zinc ores, the stamps were replaced by Schrauz mills, in order to produce less slimes. In other dressing works stamps were replaced by rolls of small diameter.

If formerly, as in various lead and zinc ore dressing works, ore of from 30 to 60 mm. size was stamped, this was a big mistake. The stamping of jig products of less than 4 mm. and of finely disseminated minerals from the medium sized jig products is to be recommended, for in this way these products can be cleaned up quicker and better, as has been fully demonstrated at Freiberg, Werlau, Ramsbeck, and Laurenburg, and long since at Clausthal.

Lührig's arrangements for jig products, in reference to further crushing, is as follows:

4-*Sieve jigs, for the sizes of 12 to 20 mm. and over.*

1-*Sieve.*—Galena to smelter.

2-*Sieve.*—Lead and blende middle product to rejigging and cobbing.

3-*Sieve.*—Rich blende middle product to cobbing or special rolls.

4-*Sieve.*—Poor blende middle product to medium rolls of blende division.

4-*Sieve.*—Tailings to the dump.

5-*Sieve jig for sizes of 4 to 12 mm.*

1-*Sieve.*—Galena to smelter.

2-*Sieve.*—Lead and blende middle product to rejigging.

3-*Sieve.*—Rich blende middle product to special rolls.

4-*Sieve.*—Poor blende middle product to fine rolls of blende division.

5-*Sieve.*—Stamp ore to stamps.

5-*Sieve.*—Tailings to the dump.

5-Sieve jigs for the sizes of ¼ to 4 mm.

1-*Sieve.*—Galena to smelter.

2-*Sieve.*—Lead and blende middle products to rejigging.

3-*Sieve.*—Blende, partly for retreating on bumping tables and jigs.

4-*Sieve.*—Blende middle product to rejigging.

5-*Sieve.*—Stamp ore to stamps.

5-*Sieve.*—Tailings, partly for rewashing on round buddles.

By this method then, only the very poor mineral of over 4 mm. which is separated on the 5th sieve is stamped. There can be nothing said in this case of too much stamping or great production of slimes, and a decrease in the loss of mineral in the tailings is noticeable, particularly in the sizes ½ to 12 mm. sizes.

Hence this method of stamping can be employed in most ore dressing works.

A gradual crushing of silver bearing ores, medium ore of 40 to 60 mm. size, has already been in use at Prebrane,* Bohemia, but not as complete a system as that of Lührig, with smaller rich ores at Freiberg, in that at the first mentioned place in the Anna roll works, the jaw crusher is missing as the first step. Then the material crushed to 20 mm. size by the coarse rolls goes directly to the medium rolls, without sizing out the liberated mineral, while

* Grundriss der Erzufbereitung von L. Kerschner, 1898.

from the latter the ore not completely crushed, over 6 mm. size, goes to the fine rolls by means of bucket elevators.

The two coarse rolls are on the fourth floor, and the medium and fine rolls on the third floor. With the coarse rolls of 650 mm. diameter, are two medium rolls of 450 mm. diameter, which crush to 12 mm. size. The material crushed by these is sized for jigging into 2–4 mm., 4–6 mm. and 6–12 mm. on bumping screens. The coarse material over 12 mm. is finally crushed on the fine rolls.

Washing and Sizing.—In later years the step form arrangement of the trommels has been departed from, as used at Clausthal and formerly at Ems. Linkenbach, as early as the seventies, arranged the trommels of each sieve in the line of their axes, in the blende division of the Silberau. See his work, "Die Aufberectung der Erze."

Civil Engineer Kley, used as early as 1871, the double trommel in the dressing works of the Grube Perm* at Ibbenbüren, Westphalia. This idea has also been used by C. Lührig in the long trommel consisting of several sieves installed in the dressing works already described.

This trommel, consisting of three or four sieves, in which a coarser sieve is jacketed around the first and finest sieve, has the advantage that they require small inclination, but also the disadvantage, that the perforations of the inner sieve cannot be washed by a sprinkler, which causes smaller sizes to reach the respective jigging ores, if the meshes become clogged. For this reason this arrangement has fallen into disuse and is replaced by long trommels, and single, trommels, arranged in a line of their axes.

With the long compound trommel, considerable diameter can be used, 1–1½ m., without requiring too much inclination, which is more effective for sizing than long sieves of small diameter arranged step form, or single trommels in a straight line.

The last two arrangements, however, have the advantage that the coarsest sizes are always separated first and do not travel over several sieves, thus increasing the wear on these. Further, the opinion is held that the sizing is closer and more accurate in single trommels than in the long compound trommels. This, however, is only true if the trommels uniformly receive the same amount of material; if the feed is not uniform, and if the trommels are forced or crowded, undersizes are carried over, which is not likely to hap-

* Nr. 45 and 46 d. B. & H., Zeit., 1874.

pen with the compound trommel with short and large diameter sieves.

In Lührig's dressing works, the mine fines and the ore crushed by the jaw crusher go to one trommel, and the product of the coarse, medium and fine rolls, goes each to one trommel. The first mentioned trommel sizes only down to 7 mm., and the trommels belonging to the three rolls size down to 4 mm. What passes through the 7 mm. sieve of the first trommel goes to the trommel of the coarse rolls. The fine of less than 7 mm. to 4 mm. hence has larger mesh to pass through, so that with the large sieve diameter, a poor sizing is out of question. All the material of less than 4 mm. from the three trommels of the rolls, goes with the stamp water to a trommel with a 3 mm. mesh placed in the rear of the stamp batteries. As considerable slime water goes to this trommel, the sieve of this is constructed of wire, which offers more resistance to the flow of the slime water than the smooth perforated sheet iron. This trommel is in connection with two more trommels, placed behind it in the same line with respectively 2 mm. and 1 mm. mesh. The sieves of the trommels treating 4 mm. and over, are made of perforated sheet iron or steel. The treating together in one trommel of the mine fine and the ore from the jaw crusher can only then be considered good where the first contains but little waste rock. In case they do, the system used in Clausthal, as early as in the sixties, is to be preferred, even in large works with two systems of apparatus. In Clausthal the mine fines and the ore from the jaw crushers are sized in separate trommels, and the cobbing ore from these are cobbed on separate tables, by which method more barren rock can be withheld from the mines fines, than if both products go to one trommel, as in Freiberg, Laurenberg, etc. In the Wellibald dressing works near Ramsbeck, where the same Lührig method was used, it has been improved by his successor, Engineer Gröppel, in that he has amplified the sizing and picking by introducing a 25 mm. sieve next to the 80 mm. one of the washing trommel, and also a double picking belt, by which the cobbing ore over 25 mm. size from the mine fines can be treated by itself.

The mesh scale, or the number of sizes made, depends entirely on the composition and nature of the ore. The former method of calculating the mesh as closely as $\frac{1}{10}$ of millimeter as at Clausthal — 32.–17.78, 13.34 – 10–7.5–5.62–4.22–3.16–.2.37–1.78–

1.33 and 1 mm. is not used any more at the present time. Whether a grain of 17.78 mm. or 18 mm. is thrown together with one down to 13 mm. makes no difference in jigging. Also to simplyfy the manufacture of sieve iron, the mesh are made only in even millimeters.

For an ore which for instance carries galena and blende, with a gangue of quartz, slate and granwacke, the largest sieve has a mesh of 30 mm. followed by 20–12–8–6–4–3 and 1½ mm. mesh.

With ore of the same minerals and gangue, in which easily dressed ores occur with such as have the minerals intimately mixed, which are difficult to dress, the first trommel, used to separate out the jigging ores, as in the mentioned Willibald mill at Ramsbeck, has but 20 mm. mesh, so that the piece of 20–30 mm. go with the cobbing ore of over 30 mm. to be picked cobbed.

In the new dressing works at St. Goar, C. Lührig made his coarsest sieve of only 14 mm. mesh, as in the place, as already mentioned, much pyrites occurs with the blende and galena.

Lately the question has been discussed in various technical journals whether the English or the German system of sizing the jigging ore is more advantageous.

The writer, during the sixties, had charge of the dressing works of the galena and blende mine, Breinigerberg near Stolberg, (Rheinland), arranged entirely according to the English system, and cannot, with his practical experience there, recommend the English system of sizing and jigging, because the loss of mineral is considerable. The tailings of the mine mentioned are quite rich in lead and zinc. The tailings from the coarse jigs were reworked later, when the mine was closed, in a primitive way, and considerable mineral was extracted. The whole tailings dump could be reworked with profit.

The method of jigging at Laurenburg, mentioned by Belloni, in his article—"Gegennvärtiger zustand der mechanischen aufbereitung in Sachsen, im Harz ünd im Rhein preussen." (Annales des Mines, Bd. xx, 4, 1891), also by Prof. Köhler im. No. 5 and 6 der Zeitschr. d. v. d. Eng., 1893, and in the article of Prof. Hoppe, Zeitschr. f. d. B. H. u. S. wesen 1 Hept., 1893,—also gives rich tailings, containing considerable blende and galena. All the tailings up to 35 mm. size is being now retreated there with profit in the dressing works built by Lührig.

With unequal sized jigging ore of —0–3, —3–15 and 15–35 mm.

as was formerly treated at Laurenburg, galena concentrates fit for smelting can be obtained from the first jigging, but not at the same time, blende concentrates and poor tailings. In but few ore dressing works, which treat galena and blende ores, is it possible to obtain blende concentrates fit for smelting from the first jigging; they are obtained mostly from the second jigging.

The first experiments made by Prof. Hoppe, had in view only the making of galena concentrates from unequaled size jigging ores, not the treating of complex ores. The losses in the tailings were not considered in the experiments.

The loss of metal in the tailings, as well as in the minerals made, *i. e.*, the loss of lead in the blende concentrates, and the loss of zinc in the lead concentrates must certainly be considered in jigging, as the loss may mean the waste of enormous quantities of metal; even with a comparatively small percentage loss, the amount sums up to great quantities in time.

In the old English system of sizing and jigging, the loss of metal is the greatest. Every ore dressing man knows that in jigging, whether it be in the English or modern way, the process becomes difficult and wasteful when a limit, either below or above certain sizes, is reached. This limit can be put down as from 2–20 mm. Above 20 mm. cleaner tailings but poorer concentrates are made; below 2mm. and jigging on a bed of concentrates, rich concentrates and rich tails are made, so that the loss of mineral in making galena and blende products is about the same in each case.

According to this practical experience, the method of sizing, proposed by Prof. Hoppe, into 35–15 mm. 15–3 mm. 3–0 mm. is not to be recommended.

In the new dressing works at Laurenburg, as is seen in the description of the same, this has not been again employed.

In many German galena and blende dressing works, however, the "wide" sizing in the upper limits is employed, *i. e.*, — 25–35, 20–30, 15–25, 12–20. A still greater range is not advisable.

It has been determined, after a months observation of the jig tailings in a modern dressing works, that the loss of mineral in the tails increases with the fineness of the sizes of grains, particularly as regards zinc.

The sizing of the jigging ores into 0–3 mm. and 3–15 mm. is hence not to be recommended, because, without a previous separation of the sands from the slimes, the tailings of the jigs would cer-

tainly contain considerable mineral in the form of slime. In some dressing works, with sand classifiers that work well, they have small spitz kasten with counter current attached to the sand jigs, to save the slimes that pass off in the tailings, showing that even the excellent bed jig is not capable of taking out the finer slime particles with the larger sands. Further and clearer proof of this is shown by the results obtained by Lührig with his excellent arrangement in this respect of the new works at Laurenburg. Lührig introduced at this place, spitz kasten to separate the slimes from the sands, in connection with the fine sand jigs. The sands are rejigged on special jigs, producing an enriched product or stamp ore, while the slimes with the waste water pass to a second spitz kasten. The slimes concentrated in this are washed on Stein tables, and show considerable gelena and blende concentrates.

In Laurenthal (Harz), long and careful experiments and trials have been carried on, in the line of Prof. Koppe's recommendations, which resulted in changing the sizes for the mine fines separation to 32–13.3 and 13.3–2 mm. (see Versuche u. Verbess, beim B. W. Betrieb in Preussen, 1894, in 3 Heft. d. Zeitschr. f. d. B. H. ü. S. w., 1895). These two sizes were jigged on two sieve jigs with slide door discharge. This method did not prove successful and was soon given up, since in 1895, in the work published for the occasion of "des. 4, allgem. deutchen Bergmannstages, at Hannover, "Das Berg und Hüttenwessen un Oberharze," it is mentioned, that the mineral of 13.2–2 mm. size, goes to rock crusher and rolls system of sizing. This sizing has very narrow limits, *i. e.*, —13.3–10, 10–7.5, 7.5–5.6, 5.6–4.2, 4.2–2.6, 2.6–1.6, 1.6–1 mm. The jig treating 32–13.3 mm. sizes furnishes no finished product; on the first sieve the product is cobbing ore, on the second, mineral to be rejigged, while the tailings go to the rolls.

In Laurenthal the mineral is principally blende, hence this ore is not suitable for jigging ore within wide limits.

It is not possible to determine the gradation and number of sizes in general; this must be determined for the case in hand.

Professor Hoppe has mentioned and pointed to the increased cost of ore dressing works, due to the employment of extensive trommel systems. He must have had in mind the extensive system in use at the Central dressing works at Clausthal. This last, however, as already described, is not modern, and has long since been replaced by simpler systems by von Rittinger, Kley, Lührig

and others. As already mentioned, a still greater simplifying of sizing, as is used at Himmelfahrt and Laurenburg, is not advantageous.

The cost of trommels for a dressing works treating 150–200 tons per shift is about 14,500 marks, which is not very great, and amounts to but about 4 per cent. of the total cost. The buildings would necessarily have the same size even if less trommels were employed.

Sizing of the Slimes.

In the sizing of the slimes, and the concentrating of the same from the waste waters, no improvement has been made recently as regards apparatus, the spitz kasten being still universally used. However, in settling the material in the waste water usually done in settling tanks, thereby seeking a complex extraction of slimes, considerable improvement has been introduced in some dressing works.

At the Central dressing works at Clausthal, these slimes were collected quite completely in settling tanks, as early as the seventies, and then removed on rotating *funnel*-shaped tables.

At the Friedrich segen mine, near Ober Lahnstein, all the waste waters of the main mill are carried to a large double spitz kasten apparatus, which is situated with nine rotating cone tables in a separate building, below the main level, and is known as the third slime wash. Each row has 24 spitz kasten, 2½ m. wide and 1.3 m. long. The discharge openings are 25 mm. wide, and made adjustable by small levers.

The waste waters flow first through one set of spitz kasten and then through the second.

In the new works at Laurenburg, C. Lührig has introduced the large 4 m. wide spitz kasten apparatus, mentioned in the first part of this paper. This apparatus treats the slimes contained in the waste waters from the sand classifiers, the jig boxes and the tables of the main works. The apparatus is divided into two halves to treat respectively the blende and galena slimes.

The "slime wennug apparatus" introduced by Lührig in the works first built by him, for the purpose of clearing those slime waters coming from the boxes of the sizing apparatus which in other places are led to waste, did not prove a success, as has already been mentioned. This apparatus consists of an endless belt,

to which scrapers are attached, for the purpose of carrying the slimes that accumulated on the floor of the basin, to a bucket elevator. The tailings of the jigs and tables were also carried to the stump of this bucket elevator. The larger grains were at once carried up by the buckets, while the slime water flowed into a long basin in which the endless belt with scrapers was in operation.

In the Willibald dressing work near Ramsbeck, there is a bucket elevator arrangement which receives the tailings from the medium and fine jigs only. In place of the endless belt with scraper, a simple spitz kasten apparatus is here used which settles better and does not cause stoppages, which happened quite often formerly because scrapers became wedged or broken.

Previous to this, in these works, the waters from the main spitz kasten, and those coming from the slime tables, which still contained considerable mineral, were thoroughly cleared and settled in special spitz kasten, because in this case the waste was not allowed to go off in the stream, but was used again in the mill. In this way some quite rich slimes are reclaimed which yield considerable blende and galena concentrates.

The turbid waste waters from the tables can be united with those from the settling boxes (Mehlfuhring), not yet sufficiently cleared and treated in the same spitz kasten apparatus. However the richer turbid waters from the *boxes of the fine concentrates and middle products* should be settled in separate spitz kasten, as in the main works at Laurenburg.

As regards the *waters from washing of the table concentrates* the device used by Lührig in the works is still better. It consists in leading the turbid waters from the cone *sumps of the tables*, each through a long row of smaller sumps, in order to get these settlings separately, and not mix them with the settlings of the rest of the turbid waters of the mill. The water coming from the last sumps is so clear that it can be used again in the mill at once.

The settling of the rest of the slime waters in spitz kasten is preferable to settling in large sumps, basins and ponds, because, aside from a great saving of room, the slimes can be washed continuously.

The ordinary spitz kasten, if built wide enough for the amount of slime water is the best concentrating and clearing arrangement. In order that the slimes shall not settle on the sides, but always

sink toward the discharge, the depth of the box should be at least equal to the width, better still if the depth is somewhat greater than the width. The waters must flow as quietly as possible through the apparatus, and the width of feed should have the full width of the first box, also the width of discharge should have the full width of the last box, in order not to produce eddies and undue currents. If the slime waters are fed by a pump, the discharge of the pump should not be directly into the spitz kasten but first into a square box placed ahead of the spitz kasten and discharging into it by a slot, or placed above it and discharging into it by holes in the bottom. If the spitz kasten is fed by launders the discharge should be spread by widening over head boards, in order to insure a quiet and even feed.

Linkenbach allows a width of 228 mm. for every 100 liters slimes per minute. The length of spitz kasten is not as important as the width, because in spitz kasten of too small a width even great length does not give as good results in classifying and concentrating the slimes, as spitz kasten of great width and less length. In the first the currents formed prevent settling.

The clearing and concentrating of slimes is also dependent on the composition of the ore. Ores having quartz, quartzites and firm limestone intermingled, clear and concentrate better than earthy, clayey or slatey ores.

Concerning the discharge of concentrates at the apex of the spitz kasten it is well to mention the improvement designed by Engineer Gröppel. He applies a water pipe with valve to the discharge pipe by which means an opposing current can be let in, thus preventing stoppage and choking of the discharge pipe which can be cleaned without unscrewing.

Sorting—cobbing.—So much has already been said about cobbing in discussing dry dressing, that it is only necessary to refer back to that and discuss here only the sorting of very difficult dressing ore.

In the new mill at St. Goar, the pieces of over 14 mm. size undergo careful cobbing on a rotating picking table in order to separate pyrite from blende as cleanly as possible since they cannot be separated on jigs.

At Selbeck (near Düsseldorf) the blende and pyrite middle products are picked down to 10 mm. sizes.

This method is to be recommended for ore containing barite

and siderite. For the separation of siderite and pyrite, the Wetherel Magnetic system can also be used, which will be further discussed in part 3.

At Ramsbeck, the pieces of 20–60 mm. and the rich jig middle products of 12–20 mm. size are picked, on account of the galena which has blende finely disseminated through it. This ore is dressed out as second-class galena, because it cannot be cleaned of blende by machinery, and if allowed to be crushed and mix with first-class galena, would depreciate the latter. In conjunction with this the clean pieces of blende are also picked out down to sizes of 12 mm.

At Ems, where much siderite, chalcopyrite and some pyrite occurs with the blende and galena, the 30–60 mm. pieces and the rich jig middle products are picked on separate tables, and clean blende, clean chalcopyrite, and siderite are separated out. The Wetherill magnetic separation would greatly aid here the dressing of the siderite and blende middle products.

The picking of pieces of 5–12 mm. is quite costly, but as long as it pays, it is the only way to separate simply and completely blende, from siderite, chalcopyrite, pyrite and barite. The same method is applicable to precious ores, for instance tetrahedrite which occurs with blende and pyrite.

As an improvement on moving belt tables or similar picking tables, a table is to be mentioned in use at the magnetic separating mill of the Hill mine in New Jersey described in section 2.

This table consists of three moving launders, the middle one of which is not loaded with ore, because it serves as a receptacle for the picked out tails which are dumped into hoppers under the table and from there go to the dump in cars.

Jigging.—Jigs vary considerably as regards the number of sieves, and are built of 2-, 3-, 4- and 5-sieve divisions.

For coarse jigging, two- and three-sieve jigs are in use at Clausthal and three-sieve jigs at Ems. In other mills and in Lührig's mills four-sieve jigs are in use for this purpose.

For the medium and fine jigging ore, five-sieve jigs are in use in many galena and blende dressing works. At Ems are used four-sieves jigs and at Clausthal three- and four-sieve jigs.

Not alone for galena and blende jigging ore, but also ore which contains but one of these minerals, or a valuable silver mineral, a jig of four sieves for coarse jigging is preferable to one of only two or three sieves.

In my opinion, five-sieve jigs should be used for all jigging ore, if the ore contains, aside from lead and silver minerals, blende, pyrite and chalcopyrite in such quantity, that middle products can be produced on the second and third sieves which lend themselves to sorting or rejigging. Two-sieve jigs are in all cases to be condemned and three-sieve jigs only to be employed where the ore contains beside the gangue only one mineral of comparitively small value. In this case the following products are obtained:

1st sieve.—Concentrates.

2nd sieve.—Middle products or ore for the rolls.

3rd sieve.—Stamp ore and tailings.

With lead or silver ores, and with good copper ores, 4-sieve jigs are requisite, as used by Lührig at Himmelfahrt. In this case the following products are obtained:

1st sieve.—Concentrates.

2nd sieve.—Middle products for rejigging or picking.

3rd sieve.—Roll ore.

4th sieve.—Stamp ore and tailings.

With several classes of ores particularly, for lead and blende jigging ores, five-sieve jigs are preferrable even for coarse sizes. As is done at Muhlenbach mine at Ehrenbreitstein, where the following products are obtained:

1st sieve.—Galena concentrates.

2nd sieve.—Middle products for rejigging or picking.

3rd sieve.—Blende—if not clean for rejigging or picking.

4th sieve.—Roll ore.

5th sieve.—Stamp ore and taiiings.

In obtaining very rich galena concentrates on the first sieve as is mostly done, it is evident that some rich galena will pass to the second sieve, where is formed a rich middle product, which contains beside galena, rich blende concentrates and roll ore, and hence cannot be directly further dressed.

At Ems this rich middle product is again returned to the same jig. In other works including Lührig's mills, the middle product is rejigged on reserve jigs, which is the more proper way. For this purpose are used continuous automatic discharge jigs, partly automatic discharge or non-automatic discharge jigs, with several or with but one sieve.

The four- and five-sieve jigs, discharging by siphon, slide or

hutch, are used to rejig the middle products of medium and fine jigs, because blende as well as galena concentrates can be made with these. For the middle products over 12 mm. size, one-sieve jigs are frequently used, in which all products are removed by hand, or the galena concentrate, removed from the sieve by siphon and only the roll ore and enriched blende products removed by hand.

Rich blende concentrates are obtained only in rare cases from jig ore of this size of over 12 mm., and only when the blende is coarse and in large quantities. The blende middle product, which is produced in this rejigging is picked on special picking tables. It pays to pick the rich jig products down to 12 mm. size after the galena and roll ores have been removed by rejigging, as has already been mentioned since more blende in coarse pieces is obtained and less is crushed to sand and slimes. This has been demonstrated by careful accounting of the work of the mills. On account of this picking work, the amount of medium and fine jigging has been considerably reduced, as is shown in the percentage of material treated in this division compared to the total of the mill. The loss in zinc has also been reduced.

With ore which contains galena and blende in about equal proportions, it is not possible to produce blende on the 3rd sieve that can be smelted, at the first jigging, that is such blende as contains at least 45 per cent. zinc and not more than 5 per cent. lead. By rejigging this product the blende is made to run 48 per cent. zinc and only 3½ per cent. lead, thus producing a very valuable zinc ore with but small loss in lead.

For the rich blende middle products from about 12 to 4 mm. which are not picked, Lührig has adopted a separate system of rolls, sizing trommels and jigs, as has been already briefly mentioned, in order to produce the blende in this material by itself as much as possible. This is a commendable arrangement.

The jig products are crushed down to 4 mm. size and are then jigged into blende concentrates of 4 to 1 or ½ mm. sizes. The material below 1 to ½ mm. size, as well as the middle products, are taken to the blende division for further dressing. In this case about 50 per cent. of the total blende product is obtained as concentrates of 4 mm. size down and as sands.

M. Neuerburg, in the Galena and Blende mill built by him several years ago at the Mathilde mine at Hamm a. d. Sieg, installed special trommels and jigs for the ore crushed by rolls, so as not to

mix it with the poorer jigging material from the mine fines and rock crushers. In this method the middle products again go to the same jigs.

This arrangement is suitable for galena and blende mills of small capacity say 75 to 100 tons per shift, but is not to be recommended for large, continuous system mills, because by its application the jig division would be of too great extent. It cannot be considered of great advantage even for small mills, because the mine fines cannot be jigged entirely separate, but go with the mineral from the rock crushers which does not materially differ from the roll ore.

In my opinion Lührigs system of treating the rich blende roll ores by themselves, and rejigging on reserve jigs the rich middle products of the ores preponderating in galena is to be preferred, because the blende can be separated more clearly and completely.

As regards the production of the blende sands (¼ to ½ mm.), a particular fact is to be mentioned. It will seem strange to many engineers, that at Ems, where modern ore dressing was introduced in the early sixties, the blende sands are worked on ordinary length percussion tables and not on sand jigs. At Ems where siderite and chalcopyrite occurs, and where they are particular for lead free blende, this percussion table method is in use. This could, however, be much aided by jigging on a bed of concentrates. The sands could very well be sorted preliminarily on this machine, where the discharge is usually continuous and direct, as follows:

1st sieve.—Clean galena concentrates.

2nd sieve.—Highly enriched blende product.

3rd sieve.—Poor tailings.

The blende product of the third sieve is usually rich in lead, and for the reason that high blende, poor lead product is desirable, is better washed on ordinary length percussion tables than on sand jigs. Lührig has applied this method in the mills at Ramsbeck, Werlau, etc. Modelling after the old works at Ramsbeck, where the blende sands were washed on Siegen percussion tables, even after the introduction of sand jigs. Lührig in the new mills uses the Salzburg bump table, built of iron, for this purpose. This table, in spite of the fact that it is larger than the Ems percussion table, is easily movable and just as effective, while the Siegen wood percussion table is usually unwieldy. The Salzburg table has a working surface of 3½ meters in length by 1 meter in width,

against the 3¼ meters length and .85 meters width of the Ems table.

The galena contained in the blende sands can be dressed out more effectively on the percussion table by aid of the "chest" than by rejigging on a bed of mineral.

As many zinc smelters charge a penalty for lead contents above 5 per cent., and as the lead contained in blende is a loss to the mill, it is essential that the blende produced shall not run above 5 per cent. of lead, which can be done even with difficult ore if the blende sands are enriched to 42 per cent. zinc by washing on percussion tables. Galena and silver minerals, on account of their greater specific gravity, are easily separated in jigging, but also in this case it is essential to have clean concentrates, particularly on account of loss of zinc, for even in ores running low in blende, considerable zinc may be lost by retaining blende in the galena and silver mineral concentrates. The percentage of zinc in galena concentrates, etc., should not exceed 5 per cent., because lead smelters deduct for an excess of zinc contents.

The jigs should produce results as rich as possible. The objection against this that this leads to loss greater than otherwise can be answered as follows:

1. *Jigging ore* containing galena and blende, the production of a rich product is justifiable because if the galena concentrates are poor in lead, they are rich in blende, since they are contaminated more by zinc blende than by gangue. Zinc blende has become a valuable mineral in recent times and hence is to be saved in every possible way.

2. *With the* employment of four and five-sieve jigs, and with the appliances of a modern sand and slime wash it is not possible to have greater loss in enriching the smelting product.

3. *The tailings* of the sand jigs are to be rewashed, as very commendably introduced by Lührig in Laurenburg, described in previous pages.

At Clausthal, the tailings from the sand jigs are led into spitz kasten, for the separation of sands from slimes. But here the sands obtained are washed on cancave buddles with felt surface while the slimes go to clearing sumps. Lührig's arrangement, with the direct washing of the slimes from these spitz kasten is to be preferred for large works.

Only in the case where galena occurs without other minerals, as,

i. e., at Mechernich, a poorer grade of concentrates is desirable, also where silver minerals occur alone as at St. Andreasberg in the Harz, where we have besides the smelters in the immediate vicinity.

Concerning the method of discharge with continuous working jigs, it is to be noted that in recent years in the Rhenish mills the discharge through a bed of mineral has for sizes above 2 mm. been discarded and the former siphon and slide discharge reinstalled. These methods of discharge have the advantage that the product discharged can be seen and observed, while with the other method the products are discharged through the hutch, and the working of the jig cannot be so well controlled. In this respect Lührig has also introduced an improvement, in that he does not make the bottom of the hutch in the form of a semi-circle, but contracts it below the sieve into a pointed box, lengthways. The concentrates can be discharged at the point of contraction by a slide discharge closed valve-like. In this way the jigman can judge of the material produced and control the jig in time. The jigs and respective hutches are placed quite high above the floor, which also serves to the better cleaning of the hutches.

Linkenbach, using the siphon discharge for the medium and coarse jigging ores of Ems, leads his discharged concentrates over a .2-meter wide board at the front side of the jig, enabling one to closely inspect the product that is made.

The Bérard slide discharge at the head and end of the sieves formerly very much used, has been replaced by small slide discharge on the side of the sieves (system Utch).

There is not much difference between the slide and siphon discharge as regards the qualitative and quantitative working of the jig. For the medium jigging ore of 2–10 mm. size, which is jigged like the sands on beds of concentrates, the siphon or slide discharge is to be preferred, as the regulating and renewing of the mineral bed is complicated and takes considerable time.

The Dressing of Slimes.—The washing of slimes,* the most difficult of the ore dressing operations has been greatly improved upon by the employment of the Stein, Schranz, and Bartsch tables.

The Stem Plane Oblique Bump Table.—This table after being described in most technical journals† and having been proven to be

* No. 14 and 15 d. B. u. H. Z., 1885, and No. 25 and 28 d. B. u. H. Z., 1895.

† No. 19 der. Besterr, Letsschr., 1890; No. 8. d. B. u. H. L., 1891, and No. 42, d. B. u. H. L., 1892.

of value at the Himmelfahrt mill by the efforts of Oberbergrath, Bilharz, Engineer Lührig and mill man Stein, has been introduced rapidly in the mills of Germany and other countries. Lührig has been most instrumental in the introduction of this table, in that he introduced it into the slime washes of the mills erected by him. This engineer has also introduced improvements as, *i. e.*, the carrying of the belt on thin rollers, in place of the Bilharz water bed, and the combination of 4 to 6 tables into the so-called compound table.

The rollers are to be preferred to the water bed on account of the diminished water consumption, and the decreased wear on the plane. Further improvements on the table have been made by Director Haber and foreman Jud at Ramsbeck, in that the wash water is applied at an obtuse angle, and the pawl and ratchet device to drive the moving roll has been replaced by a rope and pulley arrangement. With the wash water pipes at an angle the effective surface has been increased 100 per cent., and with the rope and pulley arrangement the travel of the belts and the number of the flows has been increased, thus also increasing the capacity of the table. The speed of belt in the new table is 3.75 meters and the number of blows is 180–200 per minute.

A stem table requires about 0.2 H. P. and has a capacity of 1500 to 2700 Kg. slimes (dry weight), per 10 hours. The capacity compared to the ordinary rotating slime tables is as 1 : 1½, but when compared as regards room required and first cost it has the advantage. As regards the quality of the product this table is superior to the rotating round table and also to the fixed Linkenbach round table.

Compared to the Bittinger table it has three to four times its capacity of similar slimes, and qualitatively its work is at least just as good as has been confirmed by trials at Diepenlinchen mine at Stalberg, Rheinland. To this must be added that the Rittinger table is of higher first cost and requires much more power.

The Stein table is incapable, as all other slime apparatus that are in existence at present, of producing tails poor in mineral at the first washing of fresh slimes, or by the first rewashing of middle products.

At Ramsbeck, and at the Muhlenbach mine, all the tailings from the Stein tables and other tables are taken by hand from the hutches and are rewashed on round buddles, which produce an enriched product, and tailings with small loss of lead and zinc.

Very poor tailings cannot be produced, even on a double round

rotating table, as is used, *i. e.*, at Clausthal. Even by rewashing the tailings of a slime apparatus several times the waters will always carry away mineral, which consists of such fine particles that it cannot be retained on the tables. These mineral particles comprise the greatest percentage of loss in slimes. Even with a Linken bach table of 10 m. diameter used at the zinc mine Maria at Beuthe, the tailings assayed 4 to 5 per cent. zinc, which was looked upon as good on account of the clayey nature of the slimes.

In the new mill at Laurenburg the tailings of the belt tables are rewashed on other belt tables, as already briefly mentioned.

As the slime wash of this mill is the most recent in ore dressing of the present time, it will be well to describe it in detail.

The slimes which come from the sand classifiers and from the hutches of the coarse and fine jigs are concentrated in the spitz kasten at the foot of the main mill building (Pl. I., Fig. 11). The concentrated slimes then flow into another double row of smaller spitz kasten for classification and distribution to the tables placed on both sides of the spitz kasten apparatus. In the Lührig system the tables number 32 and are placed 4 together as a compound table.

The upper 16 tables receive the slimes from the 16 spitz kasten, and produce the following products:

1. Clean galena concentrates.
2. Rich galena and blende middle product.
3. Poor galena and blende middle product.
4. Tailings.

The last three products go directly to the spitz kasten below the tables. The concentrates of these spitz kasten reach the tables on the foundation by means of siphons in the following way:

The rich middle products of the four upper tables go to a concentrating spitz kasten of 1½ sq. m. settling area, and from here go (concentrated) to one of the lower tables of the eight compound systems.

The poor middle product is treated in the same way. The tailings from four of the upper tables go to two concentrating spitz-kasten and from these to two of the lower tables.

The lower tables produce in part, more or less rich galena concentrates, and in part, smeltable blende concentrates, according to whether the slimes going to them contain galena or blende. Those concentrates which do not seem rich enough are taken from the hutches by hand and are washed on separate tables that have

stirring apparatus (either Stein, Salzburg or Schranz tables), and situated in another part of the slime division. All the rich and poor middle products as well as the tailings of the lower sixteen plane tables, are led to three places under the double spitz kasten apparatus, a centrifugal pump being situated at each point.

The poor middle products are returned by one of these pumps to the double spitz kasten, which is a perfectly correct thing to do, as their composition is the same as that of the fresh slimes. The rich middle products and the tailings, however, are each conveyed by a pump into separate spitz kasten apparatus. The settlings from these go each to two compound tables (eight single tables) placed alongside, which produce the same products. The tailings from these eight tables go again to two further spitz kasten below them, and the settlings from these go again to two compound tables (four single tables) situated below them and are rewashed here. The middle products from the above mentioned eight tables go again to one of the centrifugal pumps. The four upper plane tables also produce some galena concentrates.

The first tailings to go to the dump come from the lower four tables, so it is evident that the slimes pass over four set of tables before tailings are separated.

The overflow and waters from the spitz kasten in connection with the last tables, as well as the waters from the tailing hutches of these tables, and the overflow of the last division of the double spitz kasten are led into a clearing basin situated outside of the works. The overflow of the rest of the spitz kasten in connection with the tables is pumped back into the double spitz kasten apparatus. Below this last are placed two rows of sumps, which have been mentioned in previous pages, and which are used to clear the overflow waters from blende and galena hutches of the tables, and thus catch the fine float concentrates, enabling the waters, which in themselves are not turbid, to be used directly as they come from the end of the sumps.

The slime wash here described is very complete. There are 44 stem tables in automatic action, and only a few are worked by hand or need special attendance.

But eight boys are needed for this great number, hence the attendance necessary for the Lührig compound tables is very small indeed. A similar slime wash has been installed in the same building, for the rewashing of the old slimes of the Holzappeier mill,

which had accumulated on large clearing basins. This wash is also very efficient, and hence we will describe it in detail, as these accumulations of old slimes are of frequent occurrence and are often valuable.

These slimes are shoveled into a launder, having a perforated plate at the end with 3 mm. holes, which separates the coarse. What falls or passes through this plate goes to a bucket wheel, which elevates the slimes into a sand classifier. The sand settlings from this go to a sand jig. In connection with this classifier are the spitz kasten and tables which are of similar arrangement of those already described. Nine hands are required for this apparatus. The cost of washing is, exclusive of power and supplies hence labor alone, 4½ pf. per 100 kg. of slimes and 40 pf. per 100 kg. of concentrates. These figures are from a month's run. This shows that such slimes can be profitably treated by Lührig compound tables.

*The Schranz Convex Table.**—Besides the Stein plane table, the works also use in the slime division, the Schranz cone table, which has proved very efficient.

The mill man Schranz invented at Laurenburg a rotating table with two slime charges with bow-spayed spray, which device was also introduced at other mills, *i. e.*, at the Muhlenbach mine near Ehrenbreitstein, and at the Diepenlinchen mine at Stolberg.

The three mills mentioned seek to produce galena and blende concentrates on the tables, and for this reason the slimes are charged on the rotating tables 5½ m. in diameter in only two places, and not in more, as is claimed in the patent. (The patent has since expired.) A larger number of slime chargers is only practicable with a table of this diameter when the slimes are washed but for one kind of concentrate, because then the washing surfaces can be smaller.

Charging slimes at a number of different places on rotating tables which is also mentioned by Rittinger in his book on pages 441, 442 and 449, and by him also applied to rotating concave buddles has but one advantage, namely, that several kinds of slimes or a variety of middle products can be treated on the same table. Quantitatively a table with but one slime charge has the same capacity as a table with several slime charges, if the table surface is correctly used, as *i. e.*, in the Bartsch bump round table.

* No. 42 d. Bu. H. Zeit., 1892 and No. 26 u. 28, L. B. & H. Zeit., 1895.

In this table the slime charging apron is about 1 ¼ m. wide, while both the charging aprons of a Schranz table have only a width of 1 meter.

In the ordinary rotating convex tables the whole surface is but rarely in use, particularly in those tables where the end product is washed off by movable brushes fastened to rods, because here dead space exists between the charge apron and concentrate space, also a larger surface for the washing is required.

Of more importance than the multiple charge in the Schranz table is the curved spray. This resembles the Stein straight or angularspray as regards arrangement and effect. In both tables, the slimes approach the spray at an angle, and by this arrangement the concentrates tend to arrange themselves in regular bands. By means of this curved spray the convex table has been greatly improved. This spray requires less attendance, in that it is placed handier and has but one value for the regulation of the wash waters.

Convex tables are made of iron, cement and wood, that is, the tables proper. The well turned iron table is to be preferred to cement and wood if highly enriched products are desired, because the surface is smoother and hence the separation sharper. If the wash waters are not acid, the iron tables are practically indestructible. An iron table that has been in use at the mill of the Muhlenbach Mine, mentioned before, is practically like new after being in use for 30 years.

The Bartch Round Bump Table.—This table has a diameter of 4 meters, and rests on six rollers on which it is moved vertically and horizontally for short distances by the impact, but does not materially change its position. The motion is more of a vibratory one than anything else. The charging apron, spray and boxes for the product rotate around it as in the fixed Linkenbach table. A launder serves to catch the products, it is divided into as many parts as it is desired to make products, this launder in turn discharges each product by a pipe into other collecting launders, which are fixed and which finally discharge the products.

The impact in the Bartch table, as in the Stein and Rettinger tables, is oblique to the flow of the slimes and helps greatly to separate the different products, as has been demonstrated by working the table with and without the impact, and under other conditions

as regards charging of slime and spraying the same. Without impact the table produced no galena concentrates that could be smelted, to obtain this in the table without impact the spray would have to be much stronger, as in the Schranz table. With the aid of impact the Bartch table uses less water, which is the only advantage of this table over the Schranz table. It is a good table for mills with a scarcity of water supply.

If the Bartch table possesses this advantage in the treatment of medium and fine slimes, producing high grade concentrates, it has not as yet been demonstrated.

According to the results published in various technical journals, the Bartch round bump table (which is modelled after the Sparre shaking table, the Linkenbach and Schranz round tables) does not make cleaner products than the Schranz or the Stein table. The capacity of a Bartch table is not greater than a Schranz table. Against the small water consumption of the Bartch table may be set the smaller first cost and less repairs of the Schranz table. The last named also requires less power. A Bartch table of 4 meters diameter costs 4000 Mk. while a Schranz table of 5½ meters diameter, cement top, can be built for 1500 to 1800 Mk. With the impact appliances of the first, repairs are an unavoidable item, while only the bearing brasses of the latter have to be renewed. The impact mechanism of the Bartsch table is also not always to be depended upon. The simpler an apparatus is constructed, the easier is the attendance upon it by the millmen.

*Rotating Concave Table.**—In the dressing mills of the upper Harz, this apparatus, and the rotating convex table have been kept in use for good cause, while at other places it has been discarded.

V. Rittinger preferred the concave table to the convex table because the slimes are spread over greater area in the beginning and with less initial speed, consequently more concentrates are produced in the first washing than would be on the convex table, of which the reverse of the above mentioned properties is true.

Against this has been said that the tailings of the convex table are poorer than those of the concave. This is true, but the tailings of convex tables, even those of the large Linkenbach table are rarely so poor that they can be directly led to the dump, as has already been mentioned. For this reason, as early as 1862 the

*Zeitschryth d. B. u. H., Ver. f. Steirermark, u. Kärnten, Nr. 3, 1879 and No. 14 d. Bu. H. Zeit., 1885.

engineer Geier at Ems introduced in the galena dressing mill of his construction, the double table, consisting of a large and small convex table or of a small concave and large convex table.

The slimes were fed to the small tables, and the tailings of these washed on the large tables below them. This arrangement can still be found in the Upper Harz. Here also are found single concave and convex table, the former having the same diameter (5 meters) as the large convex tables.

The first mentioned of the above arrangement could be improved along the lines of the Lührig's compound table arrangement and, the concave tables could be improved along the lines of the Schranz convex table.

The diameter of the concave table, however must be increased to 5–5½ meters, the same as the Schranz table, in order to arrange for two slime charging aprons and the two inward curved sprays. These concave tables can be made, like a Lührig compound table, to treat two classes of slimes.

In the washing of slimes containing galena and blende, such a concave table, arranged according to the Schranz system, would produce.

First.—Galena concentrates.

Second.—Rich middle product.

Third.—Enriched blende product.

Fourth.—Poor blende middle product.

Fifth.—Tailings.

The four unfinished products cannot be led directly to tables lower down as they are discharged in too thin a condition, as has been demonstrated at the mill of the Muhlenbach mine. They would have to be concentrated in spitz kasten as in the Lührig system of compound tables. Then the two round tables could not be placed on one stem, but would be placed side by side in order to place the spitz kasten below the tables. In this case four products are to be further washed, and hence two Schranz tables would be placed in connection with one concave table making a compound system. The concave table would be placed in the middle. The one convex table with double slime aprons would receive the rich middle product, and the enriched blende product, and the other concave table, the poor middle product and the tailings from the concave table, for further treatment, after these products had been concentrated in the spitz kasten.

At the Muhlenbach mill a concave table of 3 meters in diameter has been altered to have one slime apron and a spray bent inward, the last has replaced a similar spray used to wash off the products. This small changed concave table receives the final or finest kind of slime, the bent spray works very well for washing off the products, it produces the same product qualitatively (galena concentrates up to 67 per cent. PC.), as the Schranz or Stein table. It has however been found that the inner opening of the table should be larger than usual in order to give the various products more area of discharge, which fact is of considerable influence on the capacity of the table.

The effective or working area of a concave table, fitted with a *bent* discharged spray, need not be as large as in the ordinary table with the common water launder discharge because the spray acts more intensely, as is also the case in the Schanz table.

In the last named the slimes are not charged near the axle or shaft, but about 1¼ meters distant from that, so that the working surface of the table with a diameter of 5½ m. is but 1½ meters wide at the forward end. The same working surface should be given to a concave table of 5½ meters diameter, having two slime charging aprons and a bent spray for each.

The discharge cannot be so easily regulated on a concave table as on a Schranz table, because the inside of the concave table is not as approachable as the outside of the convex table. In the latter table there can be used changeable parting boards in the launder which catches the products, as is done in the Stein table, and by changing the position of these the discharge of the product can be regulated. This cannot be done with the concave table.

Against this, however, the concave table has a greater capacity on account of the way the slimes are charged, because the charge apron of a concave table can be twice as wide as one of a convex table.

*The Linkenbach Convex Table.**—On a stationary Linkenbach convex table of 7–8 meters diameter three products can be made in treating galena and blende slimes when arrangements are similar to those of the Schranz rotating table.

With material containing but one mineral, four to five working areas can be had on a large table, these to be arranged according to the systems of Rittinger and Schranz.

* Bu. H. Zeit., 1885 and Nr. 28 d. B. & H. Zeit., 1895.

This multiple slime washing on convex and concave tables has the advantage that the attention necessary is less, and hence cheaper than with ordinary round tables. A Linkenbach table can be combined just as well with a concave table as a Schranz table for the continuous working of the unfinished products of the concave table.

The Rettinger Table.—The Rettinger bump table, which has been discarded in many dressing works on account of its small capacity, has been changed and improved by the ore dressing engineer Kavan of Pribam (see Oesterr Zeitsch., No. 8, 1895).

The dimensions of the table have been reduced as follows: Width, from 1½ m. to 0.7 meters; length, from 2.4 meters to 1 meter. Two such tables have been combined into a double table, and three double tables into a compound table. The three double tables are placed in front of each other in step fashion, are constructed lightly of wood, and hence do not require any where near as much power as the original Rittinger tables. They receive 280 to 300 impacts per minute, while the original Rittinger tables received only 100 impacts per minute at Pribam, and in Germany as many impacts as 260 were used in dressing slimes.

According to the results achieved at Pribam, the reduction in size of the table has increased the capacity considerably over the older form of table. A double table treats about 200 kg. of fine sand ¼ to ⅓ mm. in size, or about 100 kg. per single table.

For the dressing of slimes, as far as known, the Kavan table has not as yet been used. The arrangement of this table is similar to the Lührig compound table. The slimes are charged on the first double table which produces galena concentrates, giving up its middle products to the second double table and its tailings to the third double table. The first double table is connected with the second and third by means of small spitz kasten, practically the same as at the Lührig compound system, with the difference that the Lührig spitz kasten possesses greater settling surface and hence has a greater capacity.

The moderately bent spray for the washing and discharging of concentrates, similar to that employed on the Stein and Schranz tables, can here also be employed with advantage (compare No. 42 d. B. u. H. Zeit., 1892), as experiments at the Ramsbeck mills have shown.

The spray, extending along the whole side of the table, is more

intense in effect, naturally than the ordinary water supply in a short launder at the head of the table. With the spray the washing can be regulated, and the qualitative and quantitative capacity is greater than before. Aside from the shaper separation of the products the water consumption is also considerably less, hardly one-third as large as with the old method of water supply.

*The Advantages and Disadvantages of the Described Table.**— The rotating convex and concave tables are as regards construction the simplest and considering capacity not more expensive than the Stein table. They are cheaper in repairs and power, the first, as already mentioned being a very small item of expense.

The Linkenbach table is more complex in construction and the Bartch table still more so. Both tables are subject to extensive repairs on account of the many movable, respectively bumping and oscillating parts.

The Stein table is also subject to considerable repairs, much more so than the rotating tables, on account of the oscillation of the frame and the wearing of the rubber belt.

The Stein table, like the Bartch table, however, requires less water than the round tables. The Stein table compared to the Bartch table possesses the property of having a belt adjustable in inclination and twice the speed of travel, it has, however, a smaller available working area.

The first cost of a wooden plane table, when capacities are compared, is not greater than that of a convex or concave table with cement top, and is considerably smaller than that of a Bartch table, as already mentioned.

For the treatment of middle products, not alone for rich ores, but for the poor kind as well, the Stein table is preferable to all round tables, because the inclination can be accurately adjusted to the requirements of the slimes treated, and hence the various kinds of slimes be washed successively by changing the inclination.

Undoubtedly better products can be made by this table in this way than on concave or convex tables, because these latter have an inclination suitable for only one class of slimes, and it is impossible to have separate tables for all the different kinds of middle products.

The uniting of four plane tables into a compound table, requires as regards capacity only about one-half as much room as three

* No. 49 d. Oesterr Zeitschr., 1893 and Nr. 26 and 28 d. B u. H. Zeit., 1895.

convex or concave tables. This compound table is the best table for the treatment of coarse and medium slimes, as has been proven in various dressing works.

For the very finest slimes, where the bumping or shaking has very little influence, the best results are obtained, according to experiment, by the combination of a concave table 5½ mm. diameter with one or two convex tables of the same size, all supplied with double slime charge.

This table produces on this kind of slimes at the first washing a greater amount of concentrates, less middle products and poorer tailings than the compound plane tables, on account of their larger working area. The regulation of the slime charging apparatus and the spray, however, require more skill and experience with these round tables than in the plane bumping tables.

The Rittinger table possesses the same advantage of adjustible inclination that the Stein table has over the round tables. But its capacity is smaller than any of the other round tables, particularly in the treatment of slimes proper.

The choice of slime tables depends on local conditions, and the most suitable table can only be determined by competitive trial of the various kinds.

THE PARADOX OF THE PANTHEON.

By A. D. F. Hamlin.

Second Paper.

III.

The Pantheon, formerly attributed as it stands to Agrippa (27 B. C.), is now known to have been built by Hadrian, between 117 and 138 A. D., on the site of Agrippa's earlier Pantheon, which was of quite different form. It is a circular edifice, 142 feet in diameter, internally covered by a hemispherical dome 140 feet high, springing from the circular wall of the temple. This enormously massive wall is 20 feet thick (Fig. 4A), but its apparent mass is reduced one-half by a series of seven niches, *n*, opening inwards, alternately rectangular and semi-circular in plan; and an eighth which forms the great doorway: and by eight smaller semi-circular cham-

bers, opening outwards only through small windows. The eight large niches are capped by arches and half-domes, hidden by a modern wainscot or veneering of stucco. The wall appears to have been constructed in the usual way, with facings of broad flat bricks and a filling of *pozzolana* concrete. The outer brick facing, itself designed originally to be covered with marble, is now wholly bare, and is a fine example of Roman brick-masonry of a good

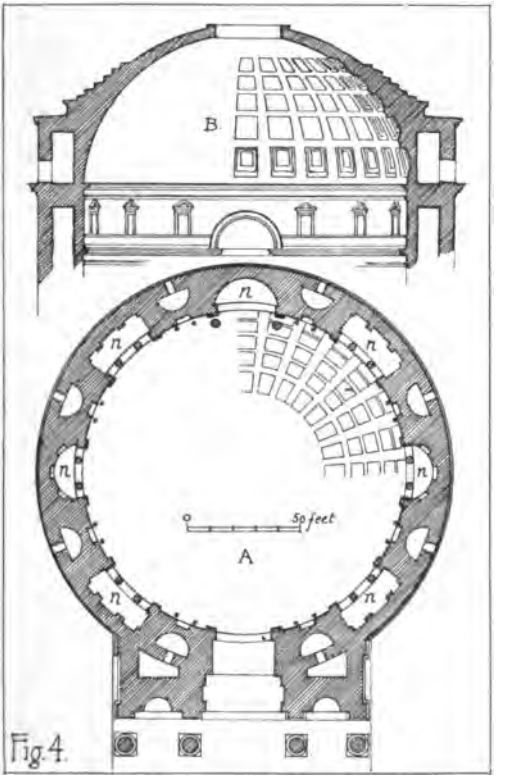


Fig. 4.

period. But the fact that by the second century A. D., the structural ingenuity and straightforward practicality of the time of Augustus had begun to be replaced by an unthinking observance of traditions and a misapplication of ingenious devices, is proved by the useless discharging arches, beautifully executed, in the upper part of this facing. Professor Lanciani has assured me that these are only one brick—*i. e.*, one foot in depth. They would have had meaning and value if they had occupied the whole thickness

of the wall and thus concentrated the bearing of the massive dome on the 16 piers or solids, separating the large and small niches; as it is they are mere "fakes," structural devices misused and pretending to a function which they do not perform, or at best merely echoing externally an internal constructive device. The cellular design of the wall is, on the other hand, admirable. The twenty feet of total thickness furnish the necessary abutment for the heavy dome (Fig. 4B), while the seven niches and the magnificent doorway which occupies the eighth both lighten the structure and embellish the interior. The dome also displays the hand of a master in its general design. It is sprung low enough to be inscribed within the square of 142 feet: the 28-foot *oculus* or eye at the summit not only lights the interior in the most beautiful manner imaginable, but relieves the dome of an immense weight at its weakest point; while the carrying up of the exterior drum to one-third the height of the dome, and the series of steps encircling the dome above it, provide for the loading of the haunches of the vault in the most satisfactory way. Very effective also, and admirably simple, is the interior panelling of the dome with 140 plain rectangular coffers, each showing four sinkages, except those of the upper or fifth tier, which have but three. The lower "rails" in each panel are wider than the upper ones, in order to render them visible to a spectator on the floor of the temple. In this interior panelled face of the vault lies the paradox of the design.

IV.

Panelled vaulting, which is a common device in Roman architecture, was derived from coffered stone ceilings like those of the *pteromata* or colonnades of Greek temples and of Roman temples built in imitation of them. This use of panels as a ceiling decoration lent itself readily to Roman methods of vaulting with brick ribs, which could be arranged to form the vertical members of the framework of the panels, while the horizontal members or "rails" of the panelling could likewise be built of brick, forming a rectangular network of brick sufficiently rigid, when set, to carry of itself the concrete filling and backing of the vault (Fig. 5). Unfortunately few large vaults remain to us constructed on this plan. The great vault of the church of S. Maria degli Angeli, at Rome, (once the tepidarium of Diocletian's baths) is internally quite smooth and plain. Others, like those of the side-chambers (all that

remain) of the Basilica of Maxentius and Constantine, are adorned with polygonal panels—large octagons and small squares, or other like combinations—which cut into and contradict any practicable

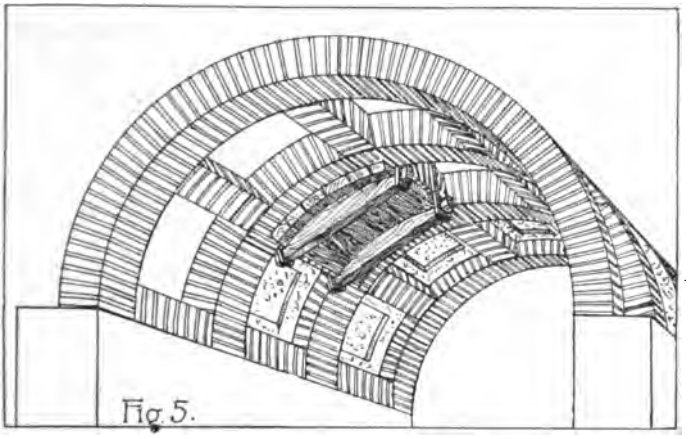


Fig 5.

system of structural ribs. I shall later have occasion to refer to the vaults of similar side-chambers in the ruins of Caracalla's baths. The one complete and monumental example of this kind of vault-decoration is the Pantheon, and here if anywhere, it would seem to be the natural and straightforward thing to allow the ribbing of the vault-panels to dictate the design of the structural framework of the dome. The interior aspect of the dome would naturally suggest a system of vertical or meridian ribs converging to the oculus, and a series of horizontal arches between them, framing the panels and stiffening the whole skeleton. But this is not at all the way the dome was actually constructed, and unfortunately it is impossible at present to say certainly how it was built. Enough, however, is clear to establish the paradox of a fundamental and confusing contradiction between the lines of the panelling and those of the structural skeleton of the dome—a discrepancy which has long been known to exist, but which the archæologists have usually ignored or passed over with a shrug of the shoulders, as a conundrum neither interesting nor important enough to bother over. The discordance was first observed when, in the course of the extensive restorations and repairs made by Benedict XIV. between 1743 and 1756, the architect and engraver Piranesi was enabled to study the construction of the dome. His drawings,*

* Piranesi, g Le Antichità di Roma: Vol. 6, pl. 28.

professedly from measurements made at this time, show a framework of eight discharging arches over the eight niches or chapels, supporting eight massive ribs springing from their crowns and braced against disruption from this heavy load by a second tier of arches sprung from the haunches (Fig. 6). This system of arches and ribs, harmonizing as it does with the general plan and construction of the wall below, has been generally accepted as correct by students of Roman art, until quite recent years. The fact that its lines cut across those of the panels, and that an eight-fold system is fundamentally inharmonious with one of twenty-eight parts, was of course patent to the most careless observer. But this did not discredit Piranesi's presentation of the structural framework of the dome, because this, if inharmonious with the panelling, was

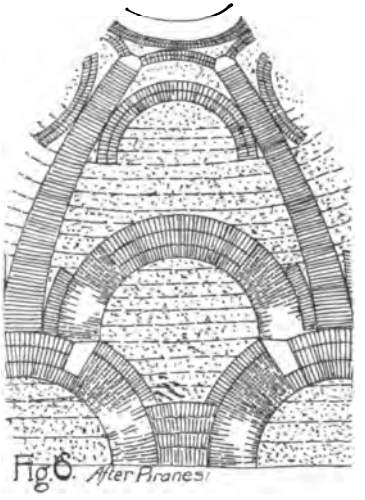


Fig. 6. *After Piranesi*

Fig. 7. *After Viollet-le-Duc*

perfectly consistent with the eight-part design of the whole interior, and the panelling was generally accepted as a decorative *appliqué* of ribs in relief, presumably in concrete or stucco, on the inner surface of the completed vault. Piranesi's sections of the Pantheon so represented it.

There were those, however, who questioned the correctness both of the Piranesi skeleton and of the theory that the panels were of concrete. Viollet-le-Duc, for instance, theorized* a preliminary inner skeleton of twenty-eight ribs and four series of horizontal

* In article "Voûte" in his *Dictionnaire raisonné de l'architecture Française du XI^e au XVI^e Siècle*, Vol. IX., p. 476. (Paris, Morel.)

arches, all of brick, and light enough to be carried by trussed centerings, forming the panelled design of the inner surface of the dome, and serving as a permanent centering for the construction of a more massive outer shell of arches and ribs after a modification of Piranesi's system (Fig. 7). This was merely one of the French writer's clever speculations; it had no basis in observed facts. Professor Josef Durm, of Carlsruhe, a reliable authority on antique architecture, in his volume on Roman architecture,* accepted this theory as a possible explanation, but with grave doubt as to its trustworthiness. The theory of two shells and two superposed frameworks he favored as quite plausible; but he was unwilling to credit Piranesi's correctness of observation, and suggested that if any such system as that shown by him had been employed, it would have had fourteen instead of eight ribs, and these would have been sprung not from discharging arches, but from the wall directly, coinciding with alternate ribs of the panelling, and allowing of the construction of the whole dome in one shell. He appears to have forgotten that such a framework of fourteen ribs would have wholly contradicted the constructive divisions of the wall on which it rested, so that in avoiding one difficulty this theory would land him in another, while reposing on nothing but Professor Durm's own speculations. He seeks to justify his discrediting of the Piranesi scheme by an unkind slur upon the honesty of that Roman, in the observation that he could have discovered the ribs and arches only by cutting through the exterior cornice and steps around the base and haunches of the dome, and that, as there is no evidence of this, "one may be led to the conclusion that Piranesi was entertaining his readers with a figment of his own imagination."

Professor Durm's contribution to the discussion added nothing to what was already known, and its attack upon Piranesi's truthfulness, being unsupported by independent observation, seemed to be contrary to the inherent probabilities of the case. Allowing for Piranesi's inaccuracy in matters of detail, it was unlikely that he should have absolutely invented his system at a time when the evidences of his fraud would have been so patent to other observers. Moreover the system he showed was perfectly in harmony with the system of discharging arches employed in the

* Handbuch der Architectur, 2ter Theil, 2 Band: *Die Baukunst der Römer.* (Darmstadt, 1885, Bergsträsser).

second story of the interior over the eight niches, and with the general plan and arrangement of the building. It seemed, therefore, more reasonable to accept Viollet-le-Duc's theory of two shells or frameworks, although without insisting upon the order in which he supposed them to have been constructed. It was possible that the outer or "Piranesi" shell had been first constructed and the panelled framework laid up afterwards, on the removal of the great centerings for the outer shell, by means of movable centerings hung from the outer framework. Each zone of the panelling would be self-sustaining as soon as completed. If thus constructed as an afterthought, perhaps when Septimius Severus rebuilt the portico, its discordance with the divisions of the dome framework was easier to understand.

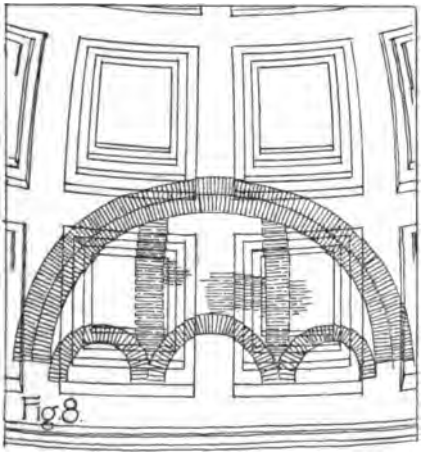
V.

It was with this theory in my mind that in July, 1894, I went to Rome with a party of students of architecture, and with them visited the Pantheon several times. As we were occupied chiefly in studying the monuments of the Renaissance, but little time was available for visiting the Pantheon.

Two years before this, Mr. Chédanne, a *pensionnaire* of the French Academy at Rome, had with the assistance and coöperation of the Italian government made an examination of the Pantheon, in the course of which he had removed the stucco from three panels of the lower row in the dome, and from several small areas near these. One result of this examination was the discovery and demonstration of the fact that the rotunda, as it stands, dates from Hadrian's time, while the portico is a reconstruction by Septimius Severus and Caracalla with the materials of Agrippa's temple-porch. About the time of my visit to the Pantheon, Mr. Chédanne's drawings were being exhibited in London, where they were the subject of discussion at the meeting of the Royal Institute of British Architects, reported in the Journal of the R. I. B. A. for 1894. The drawings and the Journal I had, of course, not seen, and Mr. Chédanne's conclusions had only been in part made public. Indeed, his full official report has not yet been published, so that at the time of my sojourn in Rome all that I had been able to learn of Mr. Chédanne's discoveries related to the dates of erection of the three successive temples upon this site.

The first thing that attracted my notice on entering the Rotonda,

(as the Pantheon is often called in Rome), was the appearance of the denuded patches of the panelled vaulting referred to above. At that distance from the eye the joints of the brick-masonry were not distinctly visible, and there was no scaffolding from which it could be examined. But in the course of a second and third visit—the latter in company with Professor Lanciani, who most kindly and graciously devoted two or three days of his very busy life to accompanying our party—careful scrutiny with the help of an opera-glass laid bare the construction of the panelling. It was clearly seen—as Mr. Chédanne's drawings, then on exhibition in London also showed it—to be wholly of brick, ribs and filling



alike; but the singular fact became apparent that it was not composed of structural ribs laid up as such, according to the theories both of Durm and Viollet-le-Duc, but was formed in the substance of the massive dome of brick, with discharging arches cutting at haphazard across the panels. Professor Durm's argument against Piranesi's system—that it was impossible except upon the theory of a double shell—was thus absolutely disproved.* Here were the arches "willkürlich durchschnittend" the caissons. The theory of a double shell, as well as that of panelling in concrete added as

* "Diese construction erscheint möglich, wenn man annimt, dass die Kuppel aus zwei übereinander liegenden Schalen besteht. In die von innen sichtbare Casseten-Kuppel ist sie nicht einzureihen, *denn Rippen und Bogen würden von den Cassetten willkürlich durchschnitten*, oder sie musste sich nur auf die oberste glatte Zone beschränkt haben," etc. (Bankunst der Römer, p. 184). [The italics are mine. A. D. F. H.]

an afterthought, was finally disposed of. The dome was a single massive vault of solid brick, an unusual construction in Rome; the panelling was formed in the brickwork itself, and this brickwork was laid up, for a part of its height at least, in a series of discharging arches. These were plainly seen to have been planned with reference to the chapels or niches below, and so far, at least, Piranesi was proved to have been correct.

But these facts merely shifted the puzzle, they did not solve it. The inherent contradiction between the twenty-eight panel-ribs and the eight-fold design of the rotunda was not explained, it was accentuated. The 140 panels were a part of the dome itself. How were they formed? How could a system of decoration so incompatible with the constructive lines and divisions of the vault have been conceived by the builders of the vault? Why should such complications of construction have been deliberately planned? How were they solved in the construction of the dome? These questions presented themselves the moment those discharging arches came to view, cutting so "willkürlich" across the ribs and panels, as may be seen in Figs. 8 and 9.

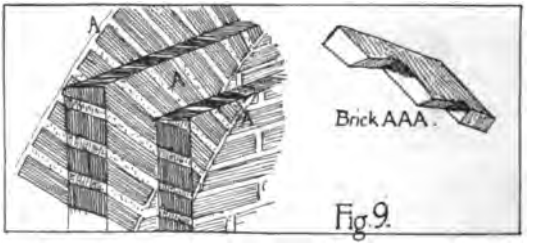


Fig. 9.

The answer that flashed across my mind almost on the instant, I have not yet found reason to discredit, for it solved all the difficulties along the line of least resistance. This is that the panelling was more or less of an afterthought, in conception, if not in time, planned as a decorative embellishment of a dome originally intended to present a smooth surface internally, and that it was *hewn in the solid brickwork* after the completion of the vault. This, at first sight, seems so extraordinary a procedure, so unlike the supposed methods of the Romans, that it appears at first incredible. But the alternative solution, although it has the support of Mr. Chédanne himself, involves such extraordinary difficulties as to demand more convincing arguments than have as yet been ad-

duced in its favor. According to this theory, the builders of the vault shaped these panels in the operation of laying up the various discharging arches of the structural skeleton of the dome. Now these panels in repeated instances completely sever the continuity of the arches for a depth of at least one layer or row of bricks. If they were planned at the outset and formed in the brickwork, they must have been completely framed in every detail in reverse relief upon a vast timber centering underlying the whole dome, each panel-mould presenting the aspect shown in Fig. 10. This is, of course, a possible thing in itself, though somewhat inconsistent with ordinary Roman methods for economizing in the centerings. Then we have to suppose the smaller centerings for the discharging arches made with their faces cut and notched to fit into all the

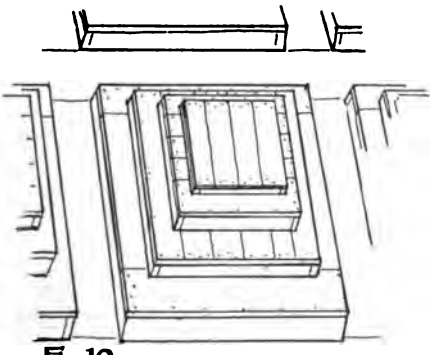


Fig. 10.

irregularities of this vast and complicated and bossy mould for the panels. As in some places the crown of an arch would lie across the bottom of the hollow trough of the mould for a panel-rib, the rest of the arch being cut off by the projecting boxes for the panels, the brick-mason would have to begin his arch at the crown, and as the inclined bricks or voussoirs reached the sides of the trough, they would have to be cut or broken to fit against it. In other places a part of the spring or haunch of the arch must be laid in the same way. These disjointed fragments of arches would have no connection or cohesion except as they were clamped or bonded to the next layer of bricks laid behind or on top of them. It would be difficult to conceive of a more unscientific, complex, difficult and foolish procedure—foolish, because wholly unnecessary. It is evident that in many places the bricks, before being

laid in place, would require to be cut with at least two notchings to fit against the steppings of the panel moulds (Fig. 9). This would be the case with bricks for the fillings as well as with those for the arches; for the photographs show that the offsets or steppings of the panels in the fillings as well as in the arches cut capriciously across the courses and jointings, and are not formed by distinct courses or layers for each offset. In no case do we find whole bricks first laid up around the box-mould, and cut or broken bricks used to fit in the fillings, as would be the case if the brickwork had been laid up on such moulds. The more one seeks to follow out the details of the process this theory supposes, the more impossible it appears. The Romans seldom hesitated at necessary expense, but they never created unnecessary difficulties and avoidable complications.

If, however, we suppose the dome to have been built first, with or without a skeleton of arches and structural ribs extending

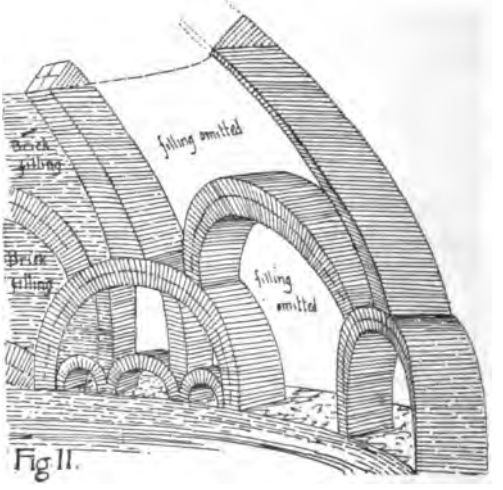


Fig 11.

through its whole thicknes, sand without regard to interior decoration, it becomes clear that this could be done with relatively light and simple trussed centerings. Chédanne has shown that the eight discharging arches are built like vertical arches, although with the inner faces shaped to the curve of the dome. If this is also true of a second row of arches (on the Piranesi theory), all the lower part of the dome could have been built up to nearly half its height without centerings (Fig. 11). As a matter of fact Piranesi's sec-

tions show all the masonry of the dome up to the level of the fourth row of panels laid up in horizontal courses, and with this Chédanne's observations agree. From that level, with the circle diminished to 80 or 100 feet, it was possible to erect eight massive ribs and the oculus at the top upon skeleton centerings, spanning the opening with trusses either resting upon the completed zone, or supported from the floor of the rotunda. Fig. 11 shows in a sketchy manner a part of the dome carried up in this manner with horizontal courses (the fillings omitted in part to show the skeleton), with the first four courses of the upper parts of two ribs laid up arch-wise. The ribs once completed were massive enough to support temporary centerings for the fillings between them. I do not say this was done; I say merely that such a procedure was possible if the builders did not concern themselves about the interior paneling. In other words, the construction of the dome, more or less *à la* Piranesi, was a comparatively simple problem, but a well-nigh impossible one if the panels were formed in the original construction.

The dome being once completed and having set, and the centerings having been removed from a part of the whole, the hewing out of the panels at any subsequent time would be a very simple matter, and would not in the least endanger the stability of the vault, which would by that time have become practically an enormously massive monolith of brick and Roman cement. The cutting of the thick discharging-arches to the depth of one or two bricks could then be done with impunity. The work would be simple, within the powers of unskilled or little-skilled laborers, and remarkable only for its quantity, not its difficulty. It would be far less difficult, indeed, than the panelling of a stone vault or ceiling. It would involve none of the complications and absurdities of the alternative theory. It is the more credible because it allows the supposition that the interior panelling was designed quite independently of the construction, so that the discordance between the two is less difficult to understand.

VI.

Against this theory there are so far as I know, but two arguments advanced. In the Journal of the R. I. B. A. already referred to, Mr. Chédanne is reported as dismissing the theory of hewn panels because of the appearance of the "surface of the bricks."

Presumably this means that the edges of bricks abutting obliquely on the edges or sides of the ribs and sinkages do not appear to have been cut, but to have been laid with their corners against the supposed rib-moulds, forming a serrated surface at such points. But it is easier to believe even Mr. Chédanne to have made a mistake in this observation than to suppose that the arches could have been built into the moulds without cutting or breaking the bricks and in most cases it would have been an absolute impossibility. On the other hand the rough hewing of the panels, to be finished afterwards in stucco, might in many places have exposed such a serrated surface as Mr. Chédanne appears to have noticed, where the ends of bricks came close to the hewing line.

The other argument is the fact that in the center of each panel is a bronze anchor set in the brickwork, to hold a bronze rosette or other ornament. It is not impossible that these were set in the brickwork after its completion: such an operation is common enough in modern work. But even were this not so, it would simply prove that the panelling had been conceived and provided for when the dome was first built, without at all proving that the panels were actually shaped in the difficult and almost incredible, if not impossible manner supposed by Mr. Chédanne. So far as the question of hewing is concerned, the evidence of these bronze anchors is irrelevant.

(*To be concluded in a third paper.*)

(*Contributions from the Havemeyer Laboratories of Columbia University, No. 18.*)

A STUDY ON THE METALLIC CARBONYLS AND THEIR DECOMPOSITIONS.

By HERMANN A. LOOS AND VICTOR LENHER.

(Read before the Columbia University Chemical Society.)

During the latter part of 1889, Ludwig Mond, while engaged in studying the by-products of the Solvay soda process, found that nickel combines with carbon monoxide to form a gaseous nickel carbonyl. He was attempting to convert the ammonium chloride produced by this process into a more available form, and for this

purpose vaporized the salt, causing dissociation into hydrochloric acid and ammonia. The acid was absorbed by some metallic oxide, and on subsequent heating in a current of air, chlorine was produced and oxide again formed; the ammonia was used over again in the soda process. The ammonium chloride vapor, however, proved to be very corrosive, so that all vessels had to be lined with glazed tiling. But valves were also necessary for changing the current of ammonium chloride to hot air and back again. Laboratory experiments showed nickel to be the most suitable substance for their construction; but when applied on a manufacturing scale they rapidly became corroded with a black crust, which was found to contain carbon. By carefully examining the crude vapor it was found that a small amount of carbon monoxide was always present; and in studying the effect of nickel on this gas, it was found to possess the property of separating carbon at a temperature of 400°, with the formation of carbon dioxide. Carbon monoxide was passed over finely-divided nickel at this temperature, and to prevent the excess of the gas from poisoning the air of the laboratory it was simply ignited and allowed to burn. When the apparatus had cooled to about 100°, the escaping gas was seen to burn with a brilliant white flame. On holding a porcelain plate in this flame, spots of metallic nickel were obtained. This was at first thought to be a new element, but was subsequently found to be pure nickel. Mond and his associates found this new gas to be a carbonyl of nickel, $Ni(CO)_4$. They determined many of its properties and succeeded in liquefying and freezing it. Naturally an attempt was made to produce other metallic carbonyls; in fact, Mond experimented with every available metal under varying conditions, and finally succeeded in producing two similar compounds with iron, having the composition $Fe(CO)_5$ and $Fe_2(CO)_7$, respectively.

The peculiar volatile compounds of some metals with carbon monoxide have recently attracted considerable attention, not only because of their scientific interest, but also from a commercial standpoint. Mond has applied the formation of nickel carbonyl to the extraction of that metal from its ores, and the "Mond Process" certainly stands unique in metallurgical practice, it being at present the only process in which a metal is separated and purified by volatilizing it in combination with a gas. Although the formation of a volatile compound with carbon monoxide from such a strongly

metallic element as nickel may be considered a remarkable fact, its successful extraction from its ores by this method seems yet more striking. An experimental plant was erected at Smethwick, England,* in 1892 and large quantities of pure nickel have been produced. The ore or matte is first brought to the condition of oxide and then ground to pass through a sixty-mesh screen. It is now treated with dilute sulphuric acid to remove most of the copper oxide. A spiral conveyer and elevator carries it to the reducing tower, where it is heated to 250° in a current of water gas. Here it is reduced to finely divided metal, is gradually cooled and then carried to the volatilizer, where the carbonyl is formed. No heat is supplied here, the gas and material itself giving the proper temperature of 50°. After filtering from dust the carbonyl passes to the decomposing cylinder where the metal is deposited on granules of nickel kept in constant motion. As the granules increase in size they are automatically removed, their grinding together while in motion producing a sufficient supply of finer particles for further deposition. The carbon monoxide produced passes back to the volatilizer. During reduction the hydrogen content of the water gas is reduced from 60 per cent. to 5–10 per cent.; the moisture present is condensed, the gas is passed through incandescent coke to reduce CO_2 to CO, and the residual gas is now used in the volatilizer. The ore is repeatedly treated and the residue is re-smelted with fresh matte. The purity of the nickel obtained in this way varies from 99.43 to 99.82 per cent. The process is simple and cost of labor and repairs is small.

Both the compounds of nickel and iron have received the attention of chemists, and their properties and decompositions have been carefully noted. Attempts have been made to prepare carbonyl compounds with other metals, but so far, it appears with but little success. Various metals have been tried by different workers but the only success that has been attained appears to be a combination that has been made by Harbeck and Lunge† in the case of carbon monoxide and palladium.

The apparently analagous derivatives which such elements as potassium seem to form with carbon monoxide, appear to be more like derivatives of complex organic acids than true carbonyl compounds.

* N. C. Roberts Austen, Proc. Ins. Civ. Eng. *135*, Nov. 8, 1898.

† Chem. Cent. *69*. 437.

Iron carbonyl is similar in properties to nickel carbonyl. It is a highly refracting liquid, boils at 105° and has a very high vapor tension. The gas decomposes at 180°, depositing a bright mirror of iron and liberating carbon monoxide. At higher temperatures much carbon will always accompany the deposit of iron. Under certain circumstances a carbonyl having the composition $Fe_2(CO)_7$ can be formed. This compound decomposes more rapidly in air and is less soluble in organic solvents than $Fe(CO)_5$.

Ferric oxide when reduced in hydrogen, gives finely divided iron, which presenting a large surface, readily enters, when gently heated, into combination with carbon monoxide passing over it. Iron carbonyl is readily formed; in fact, it is difficult to prevent its formation in the preparation of pure nickel carbonyl. When metallic nickel in finely divided condition is mixed with asbestos wool to increase the surface, iron carbonyl frequently contaminates the product, doubtlessly due to the small quantity of iron in the asbestos. Not only here do we see the ready formation of iron carbonyl, but also in the manufacture of illuminating gas, the carbon monoxide coming in contact with metallic iron such as pipes, connections, etc., frequently causes the formation of iron carbonyl which subsequently deposits iron in objectionable places, sometimes in sufficient quantity to clog up burners or interfere with the flow of the gas.

A Welsbach mantle which has been in use for a long time shows a genuine iron rust produced by the deposition of the iron from this compound and its subsequent oxidation. An interesting experiment to illustrate this point can be performed by conducting an illuminating gas (water gas) through a glass tube containing reduced iron. The tube should be gently warmed and the issuing gas burned in a Welsbach light. If the supply of air in the Welsbach light is reduced a black deposit, which consists mainly of carbon, will form on the mantle. On increasing the air supply, the carbon burns and leaves a decided dark brown stain of oxide of iron on the white mantle. Iron carbonyl has also been found in carbonic oxide which had been compressed in an iron cylinder, and the compressed gas used for the limelight. It is also said to be the cause of large deposits of oxide of iron in pipes leading from a blast furnace.

Both iron and nickel in the metallic state unite directly with carbon monoxide, at temperatures but slightly above the ordinary.

Not only does this combination take place by contact of the pure substances, but nickel carbonyl can as well be formed by such a reaction as the treatment of anhydrous nickel chloride with hot ethyl oxalate, in presence of metallic sodium (covered with petroleum ether).

Thus far iron carbonyl has only been prepared by the action of carbon monoxide on metallic iron. We tried to prepare it by the oxalic ester method, using chloride of iron instead of nickel chloride. No carbonyl could be obtained, whereupon fluoride of iron was substituted with no better results. As higher temperatures were tried, petroleum ether could not be used, so higher boiling petroleum oils were employed, and finally the oils were entirely dispensed with. At high temperatures small pieces of a lead sodium alloy replaced the sodium, but in no case could satisfactory results be obtained.

According to Frey,* when ethyl oxalate or diethyl oxalic ester is heated with metallic sodium, ethyl carbonate is formed along with carbon monoxide. The reaction takes place on gently warming.

$$(C_2H_5)_2C_2O_4 + Na = CO + (C_2H_5)_2CO_3.$$

In the presence of nickel chloride the metallic sodium seems to transform the nickel into such a condition as to allow it to readily enter into combination with the simultaneously formed carbon monoxide. Frey performs the experiment by dropping diethyl oxalic ester into a flask containing anhydrous nickel chloride or bromide, and sodium, which have been covered with petroleum ether. If the ester alone were used the sodium would float and not come in contact with the nickel chloride. We have successfully repeated this experiment, and have also obviated the use of petroleum ether by substituting for the nickel salt an amalgam of nickel with mercury and mixing with it sodium amalgam. To this end nickel amalgam was prepared electrolytically and incorporated with sodium amalgam. On covering the mass with diethyl oxalic ester and warming gently, nickel carbonyl is produced with better yield than by the method of Frey, and, of course, no petroleum ether is present to contaminate the product.

Nickel carbonyl has the formula $Ni(CO)_4$. It is a liquid with a low boiling point. It is best prepared on a small scale by pass-

* Ber. *28* (3): 2512.

ing pure carbon monoxide gas through a mass of very finely divided nickel, which presents as large a surface as possible. We have made many experiments with the view of obtaining a large yield on a small scale and our most successful operation may be described as follows:

Carbon monoxide was prepared in a pure condition either by the action of concentrated sulphuric acid on oxalic acid, or by the treatment of potassium ferrocyanide with sulphuric acid. Both methods were found to be practical for our purpose, although when oxalic acid is used, it is necessary to employ a more extensive system of washing, to absorb the large amount of carbon dioxide which is liberated along with the monoxide. In either case a series of wash bottles was introduced between the carbon monoxide generator and the nickel tubes. They contained successively water, caustic potash solution, and concentrated sulphuric acid. After being passed through this system the gas was introduced into a series of six glass tubes connected with each other in series, and filled with finely divided metallic nickel mixed with asbestos wool. This mixture is best prepared by making a paste of asbestos wool with nickel nitrate or nickel ammonium nitrate, and roasting to deadness in an open porcelain vessel, when finely divided nickel oxide is obtained. This mass is introduced into the tubes and the latter connected with a hydrogen generator. The tubes are heated in a sand bath to 400°, while a brisk current of hydrogen is passed through them. When no more water condenses on the portion of the tube which protrudes from the furnace, the reduction is considered complete.

Carbon monoxide may also be used for reduction but at the necessary temperature it is decomposed as in Mond's original experiment, with the formation of much carbon. This carbon partially protects the fine particles of nickel from intimate contact with the carbon monoxide in subsequently forming the carbonyl. The only advantage of this reducing agent is that the carbon dioxide formed is more easily removed from the tubes than the water formed by hydrogen. The tubes are then connected with the carbon monoxide generator, and when cooled to 100°, a slow current of the gas is allowed to pass through. A little nickel carbonyl comes over at this temperature, but at 60° a large yield of the gas is obtained. According to Mond, when the gas contains less than five per cent. of nickel carbonyl, it is impossible to condense it. Hence it is neces-

sary to moderate the flow of carbon monoxide in order to get a maximum content of nickel carbonyl. We were able to obtain a considerable quantity of the liquid by using a condenser cooled with ice and salt. The condenser used was made of a coil of block tin tubing one fourth inch in diameter and about ten feet long. The liquid obtained possesses all the properties ascribed to nickel carbonyl. It is a colorless, highly refractive liquid, boils at 46° and solidifies at −25°. Since it possesses a high vapor tension, it readily passes into the gaseous form, and it is from this condition that the metal is generally deposited. At 150°–180° the gas decomposes, covering objects with which it is in contact with a bright adherent layer of the pure metal. At higher temperatures as in the decomposition of iron carbonyl, carbon is also formed. This makes the coating less adherent and greatly diminishes its brilliancy. Plating of all kinds can be done by this method, either by applying the gas to the heated object or by dipping the latter into a strong solution in some organic solvent. We were unable to get good deposits by this latter method. Alloys can also be made by leading the carbonyl diluted with an indifferent gas into the molten metals which it is desired to combine with the nickel (Eng. Pat. 8083, 1891).

The deposition of a good film of metal from the gas will only take place in absence of air or in presence of an inert gas. When mixed with air, an explosive mixture is produced which detonates violently at 150°. This of course limits its use for plating. The explosion takes place according to the following equation,

$$n[Ni(CO)_4 + O] = n[Ni + C + CO_2].$$

When the gas issuing from the apparatus comes in contact with heated air (180°) it takes fire spontaneously, burning with a brilliant white flame. At the same time there is formed a small quantity of the white body, which has been described by Berthelot as always accompanying the oxidation of liquid nickel carbonyl in moist air.

The gas has a very peculiar odor and is poisonous. Injected subcutaneously the liquid produces an extraordinary reduction of temperature, sometimes as much as 12° (Mond.). Nickel carbonyl also decomposes in contact with organic matter; rubber tubing and stoppers for instance, become rapidly blackened with a covering of nickel. Berthelot has shown that when nitric oxide is

mixed with the carbonyl or when it is passed through a solution of the latter in alcohol an intense blue coloration of unknown composition is produced.

To show that the nickel is completely deposited from the gas, an experiment was devised as follows: A glass tube carrying a jet was connected with the carbonyl generator. The gas was burned at the jet with its characteristic brilliant flame. The glass tube was now heated and the nickel deposited as a bright metallic coating on the inside of the tube. This separation is very pretty. By carefully applying an ordinary Bunsen burner, the deposition of bright glistening nickel follows in the wake of the flame. At the same time the flame at the jet gradually dies down until it has only the pale blue color due to carbon monoxide. On removing the burner and allowing the glass tube to cool, the flame again brightens as the cooling progresses until it again appears brilliant at the ordinary temperature. As nickel carbonyl is very volatile, instead of collecting the liquid for experimental purposes we found it more practical to absorb it in one of its many solvents, benzene, toluene, chloroform, ether, alcohol and methyl alcohol readily dissolve it. When freshly absorbed in any of these substances a perfectly clear and colorless solution is obtained, but on standing a green precipitate forms, the nickel in time passing completely out of the solution. On looking up the literature we found that Berthelot had obtained a precipitate by allowing water to come in contact with nickel carbonyl.*

This precipitate is greenish to brown in color, and is described as free from carbon. At the same time the gaseous carbonyl which volatilized, was oxidized in the air with formation of a greenish-white body. This substance was prepared in larger quantity and subjected to analysis giving:

C	5.3	per cent.
NiO	53.3	"
H_2O	40.1	"
	98.7	"
Loss	1.3	"

Berthelot accordingly gives it the composition $C_2O_3Ni_3 10H_2O$ and concludes that it is the hydroxide of an organic radical

* Comptes Rendus 112, 1143; *ibid.*, 113, 679.

NiC_2O, with nickel as a base. This complex radical could be formed as follow: $Ni(CO)_4 + O = Ni\,C_2O + CO_2$.

The deportment of nickel carbonyl in solution is different from that in the liquid or gaseous state, as is seen for example, in the fact that it will decompose in solution at 60°, whereas, in the gaseous condition, it will not decompose until it reaches 150°. In this condition, heat decomposes it simply into nickel and carbon monoxide.

$$Ni(CO)_4 = Ni + 4\,CO.$$

In solution, the action takes a different form and may be represented as follows:

$$Ni(CO)_4 = Ni + 2C + 2CO_2.$$

Now then, it seemed probable that the precipitate obtained from the solution is different from that obtained by Berthelot from the liquid. That the precipitate is produced by the action of moisture, is shown by the fact that it forms more rapidly when the solution is exposed to the air, and still more rapidly when moist air is bubbled through the clear solution. The rapidity with which this precipitate forms varies with the solvent. In chloroform and acetone, the precipitate will form over night. With benzene and toluene, the precipitate begins to form after a few days but is not complete until after months. Benzene and toluene dissolve a large quantity of nickel carbonyl. The precipitates from these solvents are voluminous, but the deposition is only complete after long standing.

A solution in methyl alcohol remains colorless for about two months, when a slight green precipitate begins to form. The action of ethyl alcohol is peculiar. At first, the solution is colorless. Nickel carbonyl can be distilled below 60°. At 60° the usual decomposition into nickel, carbon and carbon dioxide takes place. On standing, the solution assumes a green color and has a decided smell of aldehyde. On boiling, nickel carbonyl is no longer evolved, merely a mixture of alcohol with a small amount of aldehyde distilling. On evaporation to dryness, a green deposit is left, which acts in all respects like the other green precipitates. After evaporation, this residue is no longer soluble in alcohol. The alcoholic solution of nickel carbonyl is miscible in all proportions with water. When mixed with an equal amount of water, a

clear limpid solution is obtained. In a few minutes the solution has gelatinized to a translucent substance. This precipitate will only settle after long standing. After filtering and drying, the precipitate appears to be exactly like the others.

The colors of the precipitates obtained in the various solvents vary from green to a dark-brown, the variation being due to the presence of a small quantity of iron carbonyl. In fact, iron was found in nearly all of the precipitates, and probably came from the asbestos in the nickel tubes.

These precipitates are evidently oxidation products. They are all soluble in acids with the evolution of carbon dioxide, a small amount of resinous matter which is soluble in alcohol remaining. This latter is more evident in the case of toluene, and it has a peculiar odor.

On boiling the solution of the precipitates with moderately strong sulphuric acid, carbonization takes place. Alcoholic solutions of nickel carbonyl also carbonize with sulphuric acid. Sodium and potassium hydrates remove part of the precipitate since after treatment of the precipitate with one of these alkalies and thoroughly washing, effervescence is no longer produced by an acid. Potassium iodide is without action on the precipitate, while potassium cyanide dissolves it to a brown solution. The precipitate is insoluble in chloroform, benzene, toluene, petroleum ether, alcohol, acetone, methyl alcohol or ether. Ammonium sulphide converts it into the black sulphide of nickel. The precipitates from the various solvents appear to have the same composition. The analysis of one obtained from toluene is typical and is as follows:

I.	II.
C 11.66%	C 11.38%
H 2.95%	H 2.97%
Ni 42.82%	Ni 42.68%

The formula $Ni(CO)_4$, 2 $Ni(OH)_2$ 4 H_2O requires Ni 41.26, H 2.80 and C 11.19. Since different analyses give slightly different results, it appears that the substance varies somewhat in composition as oxidation products are apt to do, although this formula does not show how carbon dioxide can be obtained by the action of an acid. Yet this can be explained by the fact that carbon dioxide is invariably a result of the decomposition of nickel carbonyl in solution.

SIMPLE TABLES FOR THE DETERMINATION OF THE COMMON OR ECONOMICALLY IMPORTANT MINERALS.*

By ALFRED J. MOSES.

In the class room and in the field there is a use for a simple tabulation of the common or important minerals by a few easily made tests and unmistakable external characters.

Such a tabulation may serve as a scheme of determination if by it the minerals are separated into small groups and in each group distinctions of composition or physical characters are suggested.

In the hands of any one with a moderate knowledge of mineralogy such a scheme is as safe and easier to use than more detailed tabulations, especially if the determination is checked by a comparison with a description of the species. If, as may happen, a specimen belongs to a rare species not included in the scheme, it will not yield tests corresponding to any species therein and more elaborate tables* will be needed.

In the tables which follow, the minerals are divided first into minerals of metallic lustre and minerals of non-metallic lustre. The minerals of metallic lustre are divided into forty-eight groups by eight horizontal divisions based on color and hardness and six vertical divisions based on the effect of the blowpipe flame on charcoal.

From the minerals of non-metallic lustre a division, *A*, of minerals possessing a taste, that is, soluble in water, is set aside. The non-metallic minerals without taste, as Division B and C, are then divided into forty-four groups, the action of hydrochloric acid giving in each four horizontal divisions, and the action upon charcoal, in *B*, and in the platinum forceps, in *C*, giving the vertical divisions.

The species in each group are printed in heavy type or ordinary type, according to their importance. The symbols, I., T., H., O., M., Tri. before each name designate the system of crystallization. In the first type *H* signifies hardness, *G*, specific gravity, *S. Ph.*, salt of phosphorus. The formula following is expected to suggest

* Compare previous tables by the author in this journal, Vol. VI., pp. 339 to 346, and Vol. XI., pp. 334 to 355.

† For instance, the Brush-Penfield Determinative Mineralogy, 15th Edition.

Not Previously Included.

The Color is Silver-White, Tin-White or Gray.

Distinctly Scratched by Calcite.

. Mercury, Hg
Fluid globules. Entirely volatilized.

Scratched by a Knife (distinctly).

H.
Ba
H.
Ti
I.
Sc

Not Distinctly Scratched by a Knife.

O.
Bl
I.
Y
I.
I.
Bl
I.
Bl
O.
Re

The Color is Black or Nearly Black.

Distinctly Scratched by Calcite.

I. **Graphite**, C
Soapy feel. Shining streak.
. **Pyrolusite**, MnO_2
Radiating or compact. Black streak.

Dist'ly Scr'd by a Knife.

O.
Co
I.
Gr

. Alabandite, MnS
Cubic cleavage. Green streak.
. **Manganite**, MnO(OH)
Prismatic. Dark-brown streak.

Not Distinctly Scratched by a Knife.

. Perovskite, $CaTiO_3$
Violet bead S.Ph. in R.F.
. Columbite, $Fe(CbO_3)_2$
Brilliant lustre. G=5.3 to 7.3
. **Uraninite**, U,Pb, Th, etc.
Botryoidal. Green S.Ph. in R.F.
. **Psilomelane**, H_4MnO_4
Botryoidal. Brownish-black streak
. Hausmannite, Mn_3O_4
Twin pyramids. Chestnut-brown streak.
. **Braunite**, $Mn_2O_3.MnSiO_3$
Black streak. Gelatinizes.
. **Rutile**, TiO_2
Violet bead S.Ph. in R.F.
. Brookite, TiO_2
Violet bead S.Ph. in R.F.

Yellow, Red, Bronze.

Distinctly Scratched by a Knife.

H.
Col

Not Sc'd by Knife.

confirmatory blowpipe tests and the lines of fine type to suggest distinctive tests or characters.

For accurate results these precautions must be taken:

1. All tests should be made upon homogeneous material, preferably crystalline, as the tests may be unreliable if the material is impure, *unless the effect of the impurity upon the test is known.*

2. The classifying tests must be *decided*, and, if weak, should be attributed either to improper manipulation or to the presence of some accidental impurity.

3. The lustre must be observed on a fresh fracture.

4. The determination must be confirmed by reference to the description of the species, and, when possible, by comparison with known specimens.

ALUMNI AND UNIVERSITY NEWS.

SCHOOL OF ARCHITECTURE.

There have been no events or changes of any great moment in the work of the School of Architecture during the past three months The most important item is the introduction into the work in Design of the fourth year, of the experiment of designing from the programmes of completed buildings or of competitions for the same, with a view to the comparison of the students' interpretation of the requirements in his finished design, with the building actually erected to meet these same requirements. The class is at present occupied with the problem of a yacht club building, the programme given out a year ago for the competition for the new New York Yacht Club House now building on Forty-Fourth Street. It is not intended that all the problems given out shall be of this character, as the imagination and inventive faculties require occasional exercise upon more or less ideal projects; but a few of these problems upon programmes actually executed impart a practical element to the work in Design which could not be otherwise assured and make possible a criticism of the students' work in the light of facts instead of theories.

A lecture by Prof. J. Liberty Tadd, of Philadelphia, on methods of education in drawing, under the auspices of the Department of Architecture, was largely attended and excited the interest and enthusiasm of the audience by the results shown in the illustrations. Lantern slides representing the pupils at work in the various schools in which Professor Tadd has applied his methods, and practical illustrations on the blackboard by three of his pupils whom he had brought with him, proved both interesting and suggestive; and the principles laid down by Mr. Tadd, and the methods employed in their application, have been the subjects of lively discussion in the Department. Rarely has a lecture proved more stimulating and suggestive to instructors and students alike.

Professor Ware's paper on "Competitions," read at the recent convention of the American Institute of Architects in Pittsburgh, and adopted by that body for insertion in its forthcoming report on competitions, has been printed in full in the *American Architect* for January 6th, December 30th. It has received the universal approval of the profession, as the clearest and fairest discussion of the ethics and procedure of competitions so far published.

In the January number of the *Brochure Series* (Boston, Bates and Guild Co.), Professor Hamlin discusses at some length the very interesting result of the recent vote by the *Brochure Series* subscribers, for the "ten most beautiful buildings in the United States." Professor Hamlin has been engaged to conduct a limited competition for a new Naval Branch of the Y. M. C. A., near the Brooklyn Navy Yard.

DEPARTMENT OF METALLURGY.

(1) Dr. Joseph Struthers retired from the tutorship in metallurgy on January 1st, and Mr. Wray A. Bentley on that day assumed the duties of lecturer on metallurgy.

(2) During the last quarter some two hundred and sixty specimens, or suites of specimens, given by fifty-four different benefactors have been added to the museum. Many of these are of very great educational value Perhaps the most important is a beautiful suite of steel ingots showing the fractures corresponding to many different compositions.

(3) An electrical resistance furnace has been added, and is now in working order. In addition, a larger one is under construction.

(4) Several important additions to the metallurgical laboratory are under consideration.

(5) Investigations into the relative merits of nickel steel, of high- and low-carbon steel, and of platinum as material for electric resistance furnaces, and into the metallography and annealing of unforged steel are being carried out by Professor Howe; and one into the metallography of malleable cast-iron, and one into the rationale of the copper refining processes by advanced students.

COLUMBIA UNIVERSITY CHEMICAL SOCIETY.

The Society was reorganized at the beginning of the fall term with the adoption of a new constitution. The principal change is the extension of membership to any officer or student in the University on recommendation of a membership committee and vote of the Society.

The following officers were elected on October 23, 1899:

Hon. President, C. F. Chandler; President, C. E. Pellew; Vice-President, J. L. R. Morgan; Secretary, H. A. Loos; Treasurer, W. P. Pickhardt; Librarian, G. B. Bernheim.

The following committees have been appointed or elected:

Executive: C. E. Pellew (ex-officio), G. C. Hubbard, W. G. Lindsey, H. A. Loos, W. P. Pickhardt.

Publication: E. H. Miller, M. T. Bogert, S. A. Tucker.

Membership: G. B. Bernheim, J. W. Masury, H. P. Tiemann.

Chairmen of Sections for Journal Reviews: Analytical Chemistry, W. G. Lindsey; Industrial Chemistry, H. A. Loos; Inorganic Chemistry, H. R. Moody; Metallurgy Chemistry, E. H. Deniche; Organic Chemistry, W. P. Pickhardt; Physical Chemistry. W. L. Hildburg.

Meetings have been held October 23d, November 5th and 16th, December 6th, 1899, and January 17, 1900.

October 23d, "The Preparation of Some Synthetic Perfums, F. St. J. Hyde; "Sulphuric Anhydride," V. Lenher; "The Mond Process for the Extraction of Nickel from its Ores," H. A. Loos.

November 5th, "Fermentation without Yeast," C. E. Pellew; "Vacuum Brewing," G. C. Hubbard.

November 16: This meeting was held at the College Tavern. Dr. Francis J. Wyatt addressed the Society on "Modern Methods of Brewing."

December 6: "Preliminary Study of the Cobalticyanides," E. H. Miller and J. A. Matthews. "The Determination of Chlorine, Bromine and Iodine," J. L. R. Morgan.

January 17: "A Laboratory Method for the Preparation of Acetylene," J. A. Matthews. "Gold Carbide," J. A. Matthews and L. L. Watters. "Some Decomposition Products of Nickel Carbonyl," H. A. Loos and V. Lenher.

Journal Reviews: "Impending Changes in the Soda Industries," Mr. C. Whitaker. "The Constitution of Camphor," D. C. Seeles. "Velvril": A New Rubber Substitute, W. P. Pickhardt.

On Tuesday evening, January 23d, Professor Chandler will speak to the Society on "An American Student in Germany—Fifty Years Ago."

LISTS OF THE ALUMNI

OF THE

SCHOOLS OF SCIENCE

OF

COLUMBIA UNIVERSITY

1900

MEMBERS OF THE ALUMNI ASSOCIATION AND OTHER GRADUATES
DETECTING ERRORS IN THE SUCCEEDING LISTS
WILL PLEASE SEND CORRECTIONS TO

PROF. F. R. HUTTON,
SECRETARY,
COLUMBIA UNIVERSITY,
OR TO
No. 12 WEST THIRTY-FIRST STREET,
NEW YORK CITY.

CONTENTS.

	PAGE
Officers of the Association,	5
Standing Committees,	6
List of all Graduates by Classes,	7
List of Members of Alumni Association (alphabetical),	19
List of Honorary Members,	98
List of Graduates not Members of Alumni Association	99
List of Members Classified by States and Towns,	123
Geographical Summary,	124
Constitution of Alumni Association,	133

SUMMARY.

All Graduates,	1237
Members of Alumni Association (all grades),	570
Associates,	17
Honorary Members,	7
Life Members,	29
Other Graduates,	556

(REVISED TO JANUARY 1, 1900.)

OFFICERS

CONSTITUTING THE

BOARD OF MANAGERS

OF

The Alumni Association of the Schools of Science

OF

COLUMBIA UNIVERSITY.

1900.

President,

HOWARD VAN SINDEREN, '81.
35 Wall Street, N. Y. City.

Vice-President,

JAMES FURMAN KEMP, '84.
Columbia University, N. Y.

Secretary,

F. R. HUTTON, '76.
Columbia University, N. Y.

Treasurer,

LEA McILVAINE LUQUER, '87.
Columbia University, N. Y.

MANAGERS.

Group.	Terms expire 1900.	Terms expire, 1901.
I.	ELWYN WALLER, '70.	J. T. WILLIAMS, '73.
II.	G. C. STONE, '79.	M. J. OCONNOR, '81.
III.	J. M. HEWLETT, '90.	D. LEROY DRESSER, '89.
IV.	JOHN SEWARD, '95.	FRED'K COYKENDALL, '92.

NOTE.—Correspondence concerning dues and other clerical details of the work of the Association may be coveniently addressed to MR. FRANCIS W. HOADLEY, Assistant to the Secretary and Treasurer, No. 12 West 31st St., New York City.

STANDING COMMITTEES.

On Badges.

F. R. HUTTON.
P. DE P. RICKETTS.

On Meetings.

JAS. F. KEMP.
F. R. HUTTON.
WALTER M. MESEROLE.

On Quarterly.

A. J. MOSES.
J. F. KEMP.
R. PEELE.
E. WALLER.
JOS. STRUTHERS.
I. H. WOOLSON.
R. E. MAYER.
W. H. FREEDMAN.

DELEGATES TO ALUMNI COUNCIL.

HOWARD VAN SINDEREN,	1900
W. B. PARSONS,	1901
JOHN A. CHURCH,	1902
D. Le R. DRESSLER,	1903
F. R. HUTTON,	1904

LIST No. 1.

Contains the names of all graduates and Members of the Alumni Association grouped by classes from the beginning. The details as to residence and Professional Occupation are given in the second or alphabetical list for convenient reference.

(Revised to January 1, 1900.)

CLASS LIST

OF

GRADUATES AND MEMBERS

OF THE

ASSOCIATION OF THE ALUMNI.

[NOTE.—Where the name is followed by a date, it denotes that the person is no longer living, and the date is the year of the death.]

1867.

Adams, J. M., 1892.
Bridgham, S. W.
Bronson, E. S.
Brown, F. G.
Church, J. A.
Cornwall, H. B.
Giddings, E. E.
Gracie, C. K., 1891.
Hale, A. W., 1899.
Harding, G. E.*
Harmer, T. H.
Heath, F. M. (formerly Petit),
Tuttle, W. W.
Van Lennep, D.

1868.

Barnard, A. P.
Baxter, G. S.
Carson, J. P.
Chester, A. H.
Coursen, G. H.
Geer, G. J., Jr.
Hanna, G. B.
MacMartin, A., 1881.
Melliss, D. E.*
Moffat, E. S., 1893.
Parsons, G. H.
Pennington, J. P.*
Pistor, W.
Platt, C. S.
Robertson, K.
Shack, A. P.
Schermerhorn, F. A.
Smith, L.
Smith, W. A., 1899.
Stalknecht, F.
Van Arsdale, W. H.
Wheeler, M. D., 1889.

1869.

Blossom, T. M., 1876.
Bruckman, F.
Campbell, A. C.
Delafield, A. F.*
Hooker, W. A.
Huntingdon, C.
Irving, R. D., 1888.
Jenney, W. P.
Munroe, H. S.
Nettre, L. R.
Newton, H., 1877.
Potter, W. B.
Randolph, J. C. F.

1870.

Haight, O., 1891.
Ingersoll, W. H.
Knapp, J. A.
Lilienthal, J. L., 1893.
Lindsley, S.
Parrot, E. M.
Terhune, R. H.
Van Wagenen, T. F.
Waller, E.

*Associate.

1871.

Fales, W. E. S.
Goldschmidt, S. A.
Gordon, J.
Ricketts, P. de P.
Riggs, G. W.
Roberts, G. S., 1898.
Robertson, R. S., Jr.

1872.

Austen, P. T.
Jenney, F. B., 1876.
McDowell, F. H.
Sloane, T. O'C.
Wendt, A. F., 1893.

1873.

Canfield, F. A.
Colton, C. A.
Mott, H. A., 1896.
Webb, H. W.
Williams, J. T., Jr.

1874.

Allen, C. S.
Benedict, W. de L.
Cameron, J. G. M., '89.
Ledoux, A. R.*
Lillie, S. M.
Murray, G.
Olcott, E. E.
Rees, B. F.
Rhodes, F. B. F.
Williams, F. H.

1875.

Ihlseng, M. C.
Iles, M. W.
Jackson, C. E.
Joy, D. A., 1888.
Lamson, R. S., 1876.
Leavens, H. W.
Macy, A., 1891.
Noyes, W. S.
Pfister, P. C.
Putnam, B. T., 1886.
Rees, J. K.
Rolker, C. M.
Russell, S. H., 1889.
Stewart, H.
Thompson, M. S.
Tucker, J. H.
Vanderpoel, F.
Wells, J. S. C.
Wetmore, E. A.
Wright, A. A.

1876.

Austin, T. S.
Bruen, F. E., 1884.
Cornwall, G. R.
Craven, F. C., 1890.
Foote, H. C., 1888.
Garrison, E. H.
Gratacap, L. P.
Hall, R. W.
Hamilton, S., Jr.
Holbrook, F. N.
Hoyt, W. L.
Hunt, F. F.
Hutton, F. R.
King, C.
Lord, N. W.
Love, E. G.
Maghee, J. H.
Morewood, H. F.
O'Grady, J. W., 1890.
Randolph, J. F.
Ross, W. C.
Schneider, A. F.
Tilden, G. C.
Van Blarcom, E. C.
Walbridge, A. C., 1892.
Wardlaw, J. R., 1891.

1877.

Barros, L. de S.
Barus, C.
Beard, J. T.
Behr, E.
Buckley, C. R.
Cady, L. B.
Canfield, A. C.
Cauldwell, J. B.
Clark, H. G., 1881.
Colby, C. E., 1897.
Constant, C. L.
Cornell, G. B.

*Associate.

Floyd, F. W.
Helleberg, F. S., 1883.
Hildreth, W. E.
Ihlseng, A. O.
Jordaõ, J. N. P.
Kelley, W.
Mackintosh, J. B., 1891.
Martin, E. W.
Murphy, J. G.
Nichols, R.
Norris, D. H.
Priest, J. R., 1880.
Radford, W. H.
Reed, S. A.
Rogers, C. L.
Sage, E. E.
Smeaton, W. H.
Smythe, R. M.
Teacher, A.
Van Boskerck, R. W.
Waterbury, C. R.

1878.

Adams, W. J.
Benjamin, M.
Blydenburgh, C. E.
Booraem, R. E.
Brinkerhoff, G. C.
Butler, W. P.
Cushman, A. R.
Davis, J. W.
Devereux, W. B.
Downing, O. P.
Drummond, I. W.
Eliot, W. G.
Fernekes, A., 1884.
Haas, H. L.
Hasegewa, Y.
Hodgse, H. A., 1883.
Holden, E. H.
Hollis, W.
Johnson, E. M.
Johnson, G. H.
Karr, C. P.
Lawrence, B. B.
Lyman, F.
Matsui, N.
McCulloh, E. A.
Morewood, G. B.
Morris, G. W., 1895.
Munsell, C. E.
Murphy, H. M., 1899.
Nambu, K.
Newberry, S. B.
Noyes, J. A.
Olmstead, O. F., 1881.
Owen, F. N.
Palmer, C. E.
Parker, R. A.
Pazos, V. F.
Perry, N. W.
Strieby, W.
Willis, B.

1879.

Bolton, R.
Britton, N. L.
Cloud, L. G.
Cornwall, H. C.
DeLuze, L. P.
Eastwick, G. S.
Haffen, L. F.
Harker, C. S.
Hathaway, N.
Hollerith, H.
Hollick, C. A.
Johnson, I. B.
Johnston, R. A., 1895.
Koch, E. C., 1898.
Leggett, T. H.
Ludlow, F.
Marsh, C. W., 1896.
Mathis, T. S.
Mayer, R. E.
Merwin, H. J.
Milliken, G. F.
Munroe, O. M.
Neftel, K.
Nesmith, J.
Noble, C. M.
Reed, W. B. S.
Rhodes, R. D.
Rutherfurd, F. M.
Sheldon, G. H., 1889.
Starr, H. F.
Stewart, F. B., 1879.
Stone, G. C.
Suydam, J. R.
Williams, G. W.

1880.

Beebe, A. L.
Benjamin, F. P., 1893.
Browning, F. D., 1885.
Browning, J. H. B.*
Brugman, W. F.
Butler, N.
Churchill, A. D., 1896.
Clark, E. P.
Elliott, W.
Engel, L. G.
Francke, R. O.
Garlichs, H.
Greene, W. U.
Greenleaf, J. L.
Hallock, A. P.
Hendricks, H. H.
Hooper, L. M.
Hopke, T. M.

*Associate.

Hudson, E. H.
Klepetko, F.
Kunhardt, W. B.
Mattison, J. G.
Meissner, C. A.
Merritt, J. H.
Navarro, J. A.
Parker, A. McC.
Parks, J. R.
Robinson, H. A.
Ruttman, F.
Singer, G.
Singer, G. H.
Smalley, W. A., 1886.
Smith, M.
Tonnelè, T.
Torrey, C. H., 1895.
Walker, J., Jr.
Wheeler, H. A.

1881.

Andresen, C. A.
Aschman, F. T.
Bleecker, C. P.
Braschi, V. M.
Bush, E. R.
Chazal, P. E.
Colby, A. L.
Curtis, C. G.
Douglas, E. M.
Dunham, E. K.
Elliott, A. H.
Furman, H. V. F.
Griswold, W. T.
Hemmer, F. A.
Judd, C. B.
Leary, D. J.
LeBoutillier, C.
Ledoux, A. D.
Little, W. P.
Meserole, W. M.
Neymann, P.
O'Connor, M. J.
O'Connor, T. D.
Pitkin, L.
Raymer, G. S.
Richmond, W. T.
Roberts, A. C.
Sawyer, C. P.
Share, W. W.
Starr, C. D.
Stearns, T. B.
Swain, A. E.
Tuttle, E. G.
Van Sinderen, A. H.
Vulté, H. T.
Williams, W. F.
Wiechmann, F. G.
Wilson, H. M.

1882.

Calman, A.
Conant, T. P., 1891.
Cooper, W. H.
Crocker, F. B.
Dougherty, O.V., 1889.
Downes, S. B., 1895.
Downs, W. F.
Emrich, A. F., 1893.
Falk, D. B.
Feuchtwanger, H.
Fitch, C. L.
Going, C. B.
Hill, W.
Illig, W. C., 1894.
Joüet, C. H.
Mesa, A. E.
Moses, A. J.
Oothout, E. A., 1894.
Page, W. S., 1899.
Parson, W. B.
Payne, C. Q.
Porter, J. B.
Powers, C. V. V.
Sands, F.
Shumway, W. A., 1892.
Staunton, W. F.
Stockwell, N. S., 1888.
Toucey, D. B.
Traphagen, F. W.
Vondy, R. H.
Wainwright, J. H.
Wanier, A. G.
Ward, N. R.
White, W. S.
Wilson, W. A.
Wittmack, C. A.
Young, E. L.

1883.

Abeel, G. H.
Adams, R.
Ayestas, A.
Balch, S. W.
Banks, J. H.
Bardwell, A. F.
Brereton, T. J.
Brewster, H. D.*
Bullman, C.
Carrére, J. M.
Channing, J. P.
Endicott, G., 1889.
Ferrer, C. F.
Ferris, J. C.
Fiallos, E. C.
Haasis, D. F.
Humbert, W. S.
Lilliendahl, A. W.

* Associate.

MacTeague, J. J.
McKenna, C. F.
Oxnard, J. G.
Painter, G. E.
Parraga, C. F.
Peele, Robert.
Powell, F.
Randolph, E.
Renault, G.
Rich, J. M.
Richardson, J. C.
Ridsdale, T. W.
Suter, G. A.
Tibbals, G. A.
Tower, A. E.
Walker, A. L.
Weed, W. H.

1884.

Adams, W. C.
Alden, H. C.
Baldwin, W. M.
Barnard, E. C.
Barratt, E. G.
Bodelsen, O.
Brinley, J. R.
Bryce, W.
Buckingham, F. E.
Burritt, W. W.
Corcoran, J. T.
Del Calvo, F.
Duncan, W. P., 1889.
Dusenberry, W. L.
Easton, L. C.
Fahys, G. E.
Fitch, J. H.
Fitzgerald, G. E.
Fowler, S. S.
Glover, C. G., 1888.
Gosling, E. B.
Griffin, S. P.
Gross, L. N.
Horn, J. T.
Kemp, J. F.
Lamb, A. J.
Luttgen, E.
McGenniss, J. W., Jr., 90.
McKim, R. A.
McLoughlin, C. S.
Miller, C. W.
Moeller, W., 1897.
Moran, D. E.
Morgan, W. F.
Mulford, R.
Napier, A. H., 1895.
Newberry, W. E., 1898.
Newbrough, W.
Nolan, T.
Northrop, J. I., 1891.
Nye, A. C.
Painter, C. A.
Pearis, C. F.
Pellew, C. E.
Post, A. S.
Powers, L. J.
Proctor, W. R.
Reckhardt, D. W.
Roeser, F.
Rood, R. G.
Rowland, C. B.
Rupp, P., Jr.
Schöney, E., 1888.
Sherman, F. D.
Slack, C. G.
Smedberg, H. A.
Snook, T. E.
Speyers, C. L.
Tibbals, S. G.
Value, B. R.
Walbridge, F. K.
Wood, G. E.

1885.

Amy, E. J. H.
Barkley, H. F., 1895.
Bemis, F. P.
Brennan, A. J.
Bush, W. F.
Cary, G.
Clark, F. S.
Cozzens, H.
Crowell, C. B.
Detwiller, C. H.
Doolittle, C. H.
Dwight, A. S.
Eddie, E. C.
Engelhardt, E. N.
Graff, C. E.
Hart, B.
Hawkes, E. McD.
Hildreth, R. W., 1895.
Hollis, H. L.
Huntington, F. W.
Ingram, E. L.
Johnson, A. G.
Lacombe, C. F.
Lee, G. B.
Mannheim, P. A. L.
Marié, L.
Merrill, F. J. H.
Meyer, H. H. B.
Miller, C. L.
Moldehnke, R. G. G.
Noble, L. S.
Norris, R. V. A.
Page, G. S.
Pierce, H. N.
Polledo, Y. Y.
Sanders, W. E.
Shope, H. B.
Starek, E.
Struthers, J.
Thomas, F. M.
Titus, W. H.
Van Cortlandt, E. N.
Watson, F. M.
Whitman, E. P.
Wiltsie, E. A.
Woolson, I. H.

1886.

Agramonte, E.
Agramonte, J. C.
Bell, H. M., Jr.
Berry, W. G.
Casey, E. P.
Conant, H. D.
Edwards, R. M.
Frankfield, E.
Good, G. McC. H.
Horn, W. D.
Howe, F.
Janeway, J. H.
Jenks, A. W.
Kissam, H. S.
Lederle, E. J.
Lee, H. C.
Newhouse, E. L.
Norton, L. H.
Ormsbee, J. J.
Osterheld, T. W.
Peck, S. B.
Porter, H. H., Jr.
Ryon, A. M.
Spooner, A. N.
Stodder, R. H., 1887.
Stuart, W. H.
Thompson, H. C.
Trowbridge, S. B. P.
Van Brunt, A. H.
Van Nardroff, E. R.
Wallace, W. J.
Wheatley, J. Y.
Wilson, C. E.

1887.

Aldridge, W. H.
Appleby, W. R.
Bellinger, H. P.
Bien, J. R.
Burns, A. L.
Burns, E. Z.
Butler, W. C.
Church, E. D.
Cole, H. M.
Congdon, E. A.
Cox, J. S., Jr.
Darwin, H. G.
Davis, C. H.
Donnell, H. E.
Ferguson, W. C. A.
Gage, S. E.
Goldsmith, B. B.
Gudeman, E.
Heinsheimer, A. M.
Huntting, H. O.
Jacobs, D. M.
Jacobs, S. J.
Jeup, B. J. T.
Lahey, J.
Lahey, R.
Luquer, L. McI.
Lusk, G.
MacKaye, H. S.
Manheim, H. C.
Marsh, J. R.
Middleton, J.
Moeller, R.
Muller, G.
Nichols, H. P.
Primelles, J. A.
Restrepo, C. C.
Rice, G. S.
Rowland, G.
Rutherford, L. H.
Schieffelin, W. J.
Seligman, J. G.
Simonds, F. M.
Slade, R. E.
Stanton, F. McM.
Staunton, J. A., Jr.
Stevens, A.
Tower, F. W.
Trask, G. F. D.
Tyler, W. L.
Warner, J. L.
Wels, P. O.
Wertheimer, L.

1888.

Allen, R. L.
Appleby, J. S.
Baker, G. L.
Bartlett, F. R.
Bechstein, C. A.
Beckwith, C. E.
Berry, G.
Colt, S. B.
Comstock, C. N.
Dodge, F. D.
Dodsworth, W. A.
Dow, A. W.
Fisher, W.
Frank, J. W.
Gardner, W. D.
Herbert, O. B.
Hopke, F. E., 1890.
Jones, W. D.
Koen, J. J.
Lenox, L. R.
Lipps, H., Jr.
McIlvaine, A. R.
Maclay, J.
Miller, R. P.
Morgan, J. L.
Munoz del Monte, A. C.
Parker, O. B., 1891.
Parsons, H.
Percival, G. S., 1892.
Perkins, T. S.
Schumann, C. H.
Shriver, H. T.
Smith, F. P.
Smyth, C. H., Jr.
Stoughton, A. A.
Taylor, J. B.
Tucker, A.
Van Volkenburgh, E.
Volckening, G. J.
Von Dyck, F.
Wampold, L.
Ward, D. W.

1889.

Atha, H. G.
Berry, G.
Brown, R. G.
Cramer, S. W.*
Cromwell, J. W.
Denton, F. W.
Dresser, D. LeR.
Eastwick, E. P.
Eilers, K. E.
Ellis, A. V. H.
Escobar, F.
Fearn, P. LeR.
Fowler, A. C.
Freedman, W. H.
Gifford, S. D.
Griffith, V. C.
Griggs, W. E.
Guiterman, E. W.
Harrington, T. H.
Harris, E.
Heinze, F. A.
Holt, M. B.
Ives, A. S.
Joplin, R. F.
Luquer, T. T. P.
Mahony, A. S.
Mapes, C. H.
Mason, C. S., 1889.
Massa, C. G.
Matthews, C. T.
Monell, J. T.
Mosley, R. K.
Oseransky, I. H.
Piez, C.
Post, A. Van Z.
Preston, W. E.
Provost, A. J., Jr.
Provot, G.
Raymond, R. M.
Raynor, R.
Rogers, O. L.
Schroeder, J. L.
Skidnore, S. T.
Small, E. M.
Smith, A.
Smith, F. M.
Stoughton, C. W.
Waters, G. S.
Wedekind, E. H.
Weekes, E. F., 1893.
Weeks, W. H.
Whitlock, H. P.

1890.

Andrews, S. W.
Beckwith, G. A.
Behlen, H.
Betts, R. T.
Black, A. L.
Blake, E. M.
Book, D. E.
Bradley, S. R.
Buckland, W. A.
Cairns, F. I.
Carson, J.
Clark, D. L.
Clayton, W. R.
Coulton, F. G.
Connell, H. R., 1895.
Coykendall, T. C.
Davis, W. M.
Deghueé, J. A.
Douglas, J. S.
Ferguson, G. A.
Fisher, L. W.
Foyé, A. E.
Gildersleeve, A. C.
Gould, E. L.
Gudewill, C. E.
Hart, C. H.
Hewlett, J. M.
Hicks, G. J., 1891.
Hinman, B. C.
Hooper, F. C.
Hoyt, J. S.
Hurlbut, E. D., Jr.
Jarmulowsky, M.
Jones, J. T.
Kohn, R. D.
Korn, L.
Levy, A. L.
Lichtenstein, E. G.
Lowndes, W. S.
McKleroy, W. H.
Mann, H. B.
Massa, L. F.
Meikleham, T. M. R.
Montenegro, M. R.
Parker, H. C.
Pearce, R.
Pelton, H. C.
Portuondo, J.
Post, W. S.
St. John, T. M.
Steers, J. R.
Thorne, W. L.
Warren, C. P.
Welch, A. McM.
Welsh, H. F.

1891.

Anderson, Geo.
Bliss, C. P.
Bookman, S.*
Blossom, F.
Boeklin, W.
Boyd, R. C.
Brosnan, F. X.
Christy, E. B.
Dunn, G. S.
Eberhardt, W. G.
Goodwin, E.
Hawley, J. F.

*Associate.

Holter, N. B.
Hornbostel, H. F.
Keeler, F. S.
Kinsey, F. W.
Langthorn, J. S.*
Leary, G.
Lilliendahl, F. A.
Livingston, A. R.
Mahl, J. T.
Mann, C. R.
Miller, E. H.
Mora, M. L.
Owens, R. B.
Raymond, A.
Skinner, E.
Strout, W. A.
Thomas, F. C.
Totten, G. O., Jr.
Tuska, G. R.
Warren, L.
Watson, R. B.
Wiener, W.

1892.

Ansbacher, L. A.
Anthon, A.*
Bergen, C. H.
Bolles, R.
Burden, H., 2d.
Casamajor, G. H.
Clark, E.*
Clarke, W. C.
Covell, E. C.
Curtiss, C. C.
Dolan, C. F.
Dufourcq, E. L.
Durham, E. B.
Dutcher, B. H.
Fenner, C. N.
Friedman, S.
Gillette, H. P.
Granger, A. D.
Harrison, N.
Hay, A.
Herckenrath, W. A.
Jackson, O.
Kletchka, J. J.
Knox, C. E.
Livingston, G.
Longacre, L. B.
Lord, F. R.
McIlhiney, P. C.
McKinlay, J. B.
Meisel, F. C. A.
Merz, E.
Parmly, C. H.
Pierce, F. E.
Reckhart, G. F.
Reese, W. W.
Ries, H.
Rosenthal, A.
Savage, S. M.
Southard, G. C.
Temple, S. J.
Towart, J.
Van Ingen, D. A.
Werner, H. C.
White, R. D.
Windecker, C. N.
Windolph, A. P.

1893.

Agelasto, M. A.
Agramonte, I. E.
Aldrich, C. H.
Ayers, W. C.
Behrmann, G. W.
Bossange, E. R.
Brooks, W. F.
Canfield, M. C.
Clark, G. H.
Covell, W. S.
Foster, R. G.
Gonzalez, A.
Gregory, L. E.
Hankinson, A. W.
Harte, C. R.
Haskell, H. G.
Hoyt, R.
Hume, F. T.
Hyde, F. S.
Jones, J. Elmer.
Kurtz, E. L.
Langmuir, A. C.
Liebmann, A.
McKee, H. S.
Macy, V. E.
Malukoff, A. J.
Matthew, W. D.
Newton, T. M.
Oakes, J. C.
Pederson, F. M.
Pomeroy, W. A.
Post, R. B.
Prince, A. D.
Provot, F. A.
Putnam, B. R.
Reynolds, M. T.
Robinson, F. G.
Schroter, G. A.
Smith, H. A.
Thompson, S. C.
Tilghman, H. A.
Tuttle, W.

1894.

Acken, B. A.
Barnett, L. K.
Black, A.
Bogert, M. T.
Buck, V. B., Jr.
Chapman, A. W.

* Associate.

Clark, L.
Cokefair, F. A.
Emery, H. G.
Fellows, W. K.
Folger, E. P.
Frisbee, H. D.
Fuentes, P.
Greene, D. J.
Hamilton, F. C.
Hanson, R. C.
Hass, E. F.
Jacobs, H. A.
Joffe, M.
Jones, E. M., 1898.
Kastner, J. C.
Leeming, T. L., Jr.
Libaire, E. W.
McNeil, C. R.
Masters, H. K
Messiter, E. H.
Mears, G. K.
Morris, B. W., Jr.
Murchison, K. M.
Munroe, M.
Osterberg, M.
Parsons, H. A.
Perrine, G.
Pope, J. R.
Prince, J. L.
Rennard, J. C.
Rittenhouse, C. T.
Searle, C. D.
Seldner, R.
Self, E. D.
Sherman, G. F. G.
Smith, W. F.
Steinam, J. L.
Stratton, Alex.
Taintor, W. N., 1898.
Tennille, G. F.
Tompkins, J. A.
Vail, L. H.
Vanderbilt, W. D.
Vatable, J. J.
Walker, H. V.
Ware, F. B.
Westervelt, W. Y.
White, T. G.

1895

Alexander, J. A.
Andrews, W. C.
Archer, G. F.
Albertson, A. H.
Barnett, L. H.
Bayles, F. P.
Baldwin, D. H.
Binion, J.
Benedikt, V. M.
Bijur, J.
Buck, H. W.
Bultman, H. D.
Candler, D. W.
Carter, B. P.
Coykendall, E.
Cox, E. V.
Dobbins, M.
Drasel, C.
Durham, H. W.
Dewey, F. H.
Evans, I. N.
Fintel E. A. von, Jr.
Fletcher, G. W.
Foerster, D.
Fox, M. J.
Gottsberger, B. B.
Gartensteig, C.
Grace, F. J. M.
Herzig, C. S.
Huntoon, L. D.
Horton, C. F.
Hadden, H. S.
Jarman, Z. H.
Johnstone, W. B.
Jobbins, F. H.
Janes, E. H.
Kirby, G. T.
Kraemer, H.
Leo, R. L.
Lum, C. H.
Macy, C. A., 2d.
McKinlay, W. B.
Miller, S. O.
Moeller, E. J.
Moisseieff, L. S.
Moses, P. R.
Mulliken, H. B.
Natkins, I.
Ormsbee, A. F.
Peugnet, C. P.
Pinkham, H.
Portuondo, J. M.
Pell, F. L.
Peppmüller, R. H.
Perrin, H. C.
Pilcher, L. F.
Reeve, F. C.
Riker, C. L.
Spaulding, M. B.
Shattuck, L. R.
Shrady, C. D.
Sutton, F.
Stewart, J. H.
Schell, R. M.
Seward, J.
Thomas, E. H.
Tucker, S. A.
Walker, F. W.
Whiting, L.

1896.

Arden, J. L.
Auryansen, F.
Benoliel, S. D.
Burrill, P. M.
Carney, E. J.
Clark, A. J.
Comstock, F. L.
Darrach, J. M. A.
Derleth, C., Jr.

Dowie, H.
Emanuel, L. V.
Franklin, L. M., Jr.
Godley, R. D.
Goldsmith, G.
Hawks, H. D.
Heye, G. G.
Holden, E. C.
Hyatt, C. E.
Hyde, H., St. J.
Lowenstein, J.
McCaffery, R. S.
McConway, W. L.
MacGahan, P.
MacGregor, D.
Hesselbach, C. V.
Metzger, A.
Monell, A., Jr.
Montgomery, H. P. A.
Morse, G. T.
Necarsulmer, E.
Of, C.
Painter, R. K.
Palmer, C. Q.
Parker, R. A.
Pemoff, J.
Perry, C. L.
Prosser, H. A.
Raymond, W. O.
Regan, G. W.
Riedel, A. E.
Rodenburg, C.
Serber, D. C.
Sergeant, E. M.
Shire, E. I.
Slichter, W. I.
Stern, H.
Tachau, W. G.
Thyng, W. S.
Toch, M. B.
Tompkins, E. De V.
Townsend, S. G. F.
Tubby, J. T., Jr.
Uhling, W. C.
Van Benthuysen, B.
Van Gelder, A. P.
Van Vleck, J., Jr.
Wells, D. C.
Witherell, C. S.
Woodruff, G. W. L.

1897.

Adams, E. K.
Barnes, W. C.
Bates, P. A.
Baxter, D. E.
Bellman, J. J.
Bishop, R. R.
Boehm, G. A.
Boerner, E. C., Jr.
Brown, A. M.
Burroughs, H. S.
Chatain, H. G. F. J.
Clark, C. M.
Clark, J. H.
Collins, C. L., 2d.
Congdon, H. W.
Coykendall, F.
Crampton, S. H.
Davidson, W. S.
Farmer, A. S.
Force, D. N., Jr.
Fulton, C. H.
Gill, A. W.
Goodridge, J. W.
Gotthelf, A. H.
Haldy, G. F.
Hildburg, W. L.
Holbrook, F. M.
Humphreys, J. B.
Herz, H.
Koch, R.
Kaufman, E.
Kilian, W. G.
Knox, N. B.
Lane, R.
Loewenthal, M.
McLean, J. M.
MacMullen, C. W.
MacClelland, J. B.
Maben, J. C., Jr.
Madden, J. H.
Manheims, L. R.
Magalhaes, G. W.
O'Reardon, I.
Perkins, S.
Prosser, H. A.
Ralph, H. P.
Rogers, C. E.
Riederer, E. J.
Rappold, G. W.
Sayres, J. H.
Schlecht, W. W.
Stander, I.
Stout, J. S., Jr.
Smith, O. B., Jr.
Taylor, A. S. G.
Tibbals, R. G.
Van Deventer, C.
Van Dyck, W. V. B.
White, L.
Waldenberger, C. A.

1898.

Anthon, G. C.
Arendt, M.
Beadel, H. L.
Beatty, A. C.
Bennett, G. L.
Bentley, W. A.
Bostwick, W. A.
Bracket, G. S.
Brown, H. D.
Burns, W. G.
Burnside, C. H.
Campbell, A. J.

Caswell, K. L.
Coffin, Tristram R.
Chibas, L. F.
Conover, J. T.
Daly, E. H.
De Coppet, T.
Dunn, A. D.
Eckerson, C. H.
Ferguson, G.
Foote, E., Jr.
Gallatin, A. R.
Geppert, R. M.
Goodman, J.
Gotchall, L.
Gumaer, A. H.
Gunn, G. B.
Haight, C. S.
Haskell, G. M.
Hill, R. F.
Hodgson, E. H.
How, R. W., Jr.
Hutchins, G. L.
Jones, J. E.
Jones, W. P.
Joseph, T. H.
Judson, H. C.
Kipp, B.
Krumb, H.
Le Prince, J. A. A.
Levine, E. J.
Lewis, C. MacK.
Lighthipe, W. W.
Lichtenstein, H.
Lowenberg, L.
Livingston, J., Jr.
Lobo, G.
Lowther, C. M.
Lucas, G. L.
Lydecker, I. S.
McClure, W. J.
McClellan, H.
Machen, H. B.
Magruder, H. S.
Martin, L. T.
Mason, F.
Menline, I.
Mitchell, H. B.
Mortimer, H. C., Jr.
Newman, M. L.
O'Connor, J. W.
O'Connor, W. A.
Otto, C. L.
Parsons, W. E.
Pattberg, O. F.
Peck, T. B., Jr.
Raymond, Max.
Raisman, A. I.
Reyna, J. E.
Rogers, A. P.
Ros, J. P.
Ropes, Wm.
Saunders, G. C.
Schimmel, J., Jr.
Sessinghaus, G.
Smith, W. A., Jr.
Stilwell, A. G.
Sturgis, E. B.
Sutro, H. H.
Tatlock, J. L.
Thomas, W. S.
Titcomb, H. A.
Trapote, R.
Tudor, W., Jr.
Van Voorhis, B. W., 2d.
Vredenburg, W., Jr.
Wagnall, Otto.
Ware, Arthur.
Watson, William.
Weeks, R. D.
Wolff, H. H.

1899.

Aylmer-Small, C. S.
Bauman, A. P.
Beck, O. C.
Benedict, Eli.
Berger, John.
Blondel, T., Jr.
Blum, E.
Boyd, J. D.
Cabot, John, Jr.
Cairns, B. S.
Carpenter, H. C.
Chapman, H.
Clark, W. G.
Cogan, H. M.
Crawford, H. E.
Delson, I.
Dickerson, F. S.
Dieterich, A. E.
Durham, L.
Ehrenreich, J. J.
Entz, G. G.
Falk, M. S.
Fechheimer, A. L.
Ferguson, Samuel.
Fisher, H.
Fliess, R. A.
Foster, O. R.
Hall, H.
Hawkins, S. O.
Heike, R. E.
Henderson, H. H.
Hudson, P. K.
Hulbert, C. S.
Jung, A. N.
Kneeland, F. R.
McCulloch, R. A.
McIntyre, H. K.
Machen, C. H.
Mainzer, H. R.
Moschkowitsch, M. S.
Muller, Julius.
Murphy, G. R.
Orner, G. D.
Perkins, H. A.
Riter, L. E.
Schroeder, H.
Schulte, E. D.
Scudder, H., Jr.
Simonson, L. M.
Slaven, R. E.
Stratford, T. A.
Van Wagenen, H., Jr.
Weinstein, M.
Wright, R. G.

LIST No. 2.

This list embraces the members of the Alumni Association of the Schools of Sciences of Columbia University under the Constitution of that body. It is urged that all graduates of the school should list themselves under this group. Names not found here are grouped in List No. 3, which includes graduates who are not also members. All graduates are requested to try to make and keep this list correct and accurate.

(Revised to January 1, 1900.)

MEMBERS

OF

The Alumni Association of the Schools of Science

OF

COLUMBIA UNIVERSITY.

A.

ABEEL, GEORGE HOWARD, E.M., ... 1883.
Box 642 Hurley Iron Co., Wis. Also 5 East 124th St., New York, City.

1883–84, Chemist Iron Cliffs Co., Negaunee, Mich. 1885–88, Assistant Manager Cliffs Co., Negaunee, Mich. 1886–1887, Supt. Negaunee Gas Light Co., Mich. 1888–89, Manager Ironton Iron Mining Co., Bessemer, Mich. 1888–89, Agent Pilgrim Mining Co., Bessemer, Mich. 1889, Supervisor Bessemer Township, Gogebic Co., Mich. 1889–92, Agent Ruby Iron Mining Co., Bessemer, Mich. 1888–95, General Manager Montreal River Iron Mining Co., Hurley, Wis. 1892–94, Vice-President First National Bank, Hurley, Wis. 1892 to date, Vice-President Wisconsin Mining Supply Co., Hurley, Wis. 1893, Vice-President and General Manager Section 33 Iron Mining Co., Hurley, Wis. 1894, Consulting Engineer Newport Mining Co., Supervisor, Town of Vaughn.

ADAMS, ERNEST K., PH.B. (Yale), E.E., M.A., . . 1897.
455 Madison Avenue, New York, N. Y.

ADAMS, RANDOLPH, E.M., ... 1883.
General Manager Tennessee Copper Co., Copperhill, Polk Co., Tenn.

1883–85, Chemist and Engineer in Dept. for Testing Materials; Erie Railway, Susquehanna, Pa. 1886, Foreman of Mill—dry crushing, chlorination and amalgamation—for Silver King Mining Co., Pinal, Ariz. 1887–88, Assistant Superintendent and General Superintendent for the Silver King Mining Co., Silver King, Ariz. 1889–91, went to New South Wales, Australia, on two-years' engagement as General Manager of Webb's Silver Mining Co., Ltd., Sidney. 1891–95, General Manager of the "Central" Broken Hill Mine, New South Wales; for the Central Broken Hill Silver Mining Co., of Sydney and Melbourne. During above engagement was also General Manager for the two adjoining properties, viz: The Central Block Silver Mining Co., Ltd., and the North Central Silver Mining Co., N. L., of Sidney. 1895–97, General Mining Manager, at Broken Hill, for the Sulphide Corporation (Ashcroft's Process), Ltd., of London and Melbourne. During engagement in Australia also made special mining and treatment reports

on various silver, gold and copper properties, throughout Queensland and New South Wales. 1896 and 1897, President of the Broken Hill Branch, of the Australian Mining Manager's Association, Broken Hill, New South Wales. 1899 to present, General Manager, Tennessee Copper Co., Copperhill, Tenn.

ALDRIDGE, WALTER HULL, E.M., ... 1887.
Canadian Smelting Works, Trail, British Columbia.
And *for mail* 203 Montague Street, Brooklyn, N. Y.

Beginning July, 1887, Assayer at Colorado Smelting Co., Pueblo. At different times, Chemist of Colorado Smelting Co., Pueblo. August 1890-91, Assistant Superintendent and Metallurgist of Colorado Smelting Co., Pueblo. 1892, Assistant Manager United Smelting and Refining Co. 1893 to November, 1897, Manager United Smelting and Refining Co., E. Helena, Mont. November, 1897, accepted position with Canadian Pacific Railway as Consulting Mining Engineer and Manager of their Smelting Works.

ALLEN, ROBERT LAWRENCE, A.M., E.M., . . . 1888.
102 Cambridge Place, Brooklyn, New York.

AMY, ERNEST JULIUS HYACINTHE, A.B., E.M. . . 1885.
Durango, Colo.

1885–86, Chemist and Assayer at works of the San Juan and N. Y. M. and S. Co., at Durango, Colo., with the exception of three months' professional visit to Old Mexico. 1886-87, Assistant Manager of the San Juan and N. Y. M. and S. Co., at Durango, Colo. 1887-88, Manager of the Hazleton Mountain Mining Co., at Silverton, Colo. 1888 to April 1, 1890, Assistant Manager of Works of the San Juan Smelting and Mining Co., at Durango, Colo. (The S. J. S. and M. Co. being formed by the consolidation of the S. J. and N. Y. M. and S. Co., of Durango, and the Hazleton Mt. Mfg. Co., of Silverton, Colo.) 1890–99, General Manager of the San Juan Smelting and Mining Co., at Durango, Colo.

ANDREWS, SAMUEL WAKEMAN, JR., PH.B. . . . 1890.
35 W. Forty-second Street, New York City.

1890-91, Designing with Tiffany Glass and Decorating Co., New York. 1891–98, member of firm Andrews, Waters & Sherwin.

ANDREWS, WILLIAM C., E.E., ... 1895.
Assistant in Physics, Columbia University, New York City, and Hotel Margaret, Brooklyn, New York.

ANSBACHER, LOUIS RUDOLPH, PH.B., ... 1892.
A. B. Ansbacher & Co., Color Manufacturers, 4 Murray Street and 15 West 75th Street, New York City.

ANTHON, ARCHIBALD, E.E. (Associate), ... 1892.
13 W. 35th Street, New York City.

APPLEBY, W. R., A.B. (Associate), ... 1887.
Professor of Mining and Metallurgy, School of Mining and Metallurgy, University of Minnesota, and 911 Fifth Street, S. E., Minneapolis, Minnesota.

ATHA, HENRY GURNEY, PH.B., A.M. (Williams), . 1889.
Care of the Benjamin Atha & Illingsworth Co., Harriston, and 89 Clinton Street, Newark, N. J.

AUSTEN, PETER TOWNSEND, PH.B., PH.D., . . . 1872.
Austen Chemical Research Co., 52 Beaver Street, New York City and 218 St. Johns Place, Brooklyn, N. Y.

1878–80, Assistant Professor of Analytical Chemistry, Rutgers College. 1880-89, Professor of General and Applied Chemistry, Rutgers College. 1891, Superintendent Manufactories of W. J. Matheson & Co., limited, Ravenswood, N. Y. 1892, General Manager, Ledoux Chemical Laboratory. 1893, Professor of Chemistry, Polytechnic Institute, Brooklyn, N. Y. 1897–98, Chief Chemist, Publishing Advertising and Trading Syndicate. 1898-99, Chief Chemist Am. Pegamoid Co., N. Y. 1899 to date, President Austen Chemical Research Co.

AUSTEN, THOMAS SEPTIMUS, E.M., ... 1876.
Chihuahua Mining Co., Chihuahua, Mexico.

1877-78, in Cuba as Chemist. 1879-80, Assayer Germania Smelting Co. 1880-90, Superintendent Rio Grande Smelting Co., Socorro, N. M.

B.

BALCH, SAMUEL WEED, E.M., ... 1883.
M. E. and Solicitor of Patents, 41 Wall Street, New York City.

1883–84, Otis Elevator Co. 1884–86, Mowing Machines. 1886–89, Garvin Machine Co., Tools and Special Machinery. 1889 to date, General consulting practice as Mechanical Expert and Patent Attorney. Specialty, Difficult Mechanical Problems.

BALDWIN, WILLIAM M. PH.B. (Life Member), . . 1884.
New York and Boston Dyewood Co., 55 Beekman St., New York City, and Garden City, Queens Co., New York.

Since 1885, Chemist for the New York Dyewood Extract and Chemical Co., Since 1888, Vice-President of the above corporation, and Manager of same from 1892 to date.

BANKS, JOHN HENRY, E.M., PH.D., ... 1883.
104 John Street, New York City, and Boonton, N. J.

1883–85, Chemist with Ledoux & Ricketts, New York. 1885–91, Private Assistant to Prof. Ricketts, School of Mines, New York, in general analytical, metallurgical and mining engineering work. 1889–91, Hon. Fellow in Assaying, School of Mines. 1894 to date, in partnership with Prof. Ricketts, at above address, in general chemical, metallurgical and mining engineering work, with Ore Testing Works, at Waverly, New Jersey, for determining treatment of ores and examination of processes.

BARNARD, EDWARD CHESTER, E.M., ... 1884.
U. S. Geological Survey, Washington, D. C.

Assistant Topographer and at present Topographer in the United States Geological Survey, 1884–91. Have been engaged in mapping in Virginia, West Virginia and the mountains of East Kentucky. 1893, mapping northern New York.

BARNETT, L. H., E.M., ... 1894.

Assayer of Enterprise Mining Co., Rico, Colo., and 295 Columbus Avenue, New York City.

1895, Field Assistant U. S. Geological Survey. 1896, Assistant Chemist Philadelphia S. & R. Co., Pueblo, Col., and Mining Engineer Enterprise Mining Co., Rico, Col. 1897, Mining Engineer, Enterprise Mining Co., Rico, Col.

BARRAT, EDGAR GRANT, C.E., ... 1884.

1601–3 Fisher Bldg., Chicago, Ill., and Kenilworth, Ill.

1884-88, Engineer for The Exhaust Ventilator Co. 1888 to date, President and Proprietor of the Exhaust Ventilator Co. 1891 to date, President and General Manager of the Variety Manufacturing Co. Fill the above positions at present and am consulting Ventilating and Heating Engineer. 1897, Manager of Fisher Building, Chicago. Consulting Engineer, The Union Bag and Paper Co.

BARUS, CARL, PH.D. (Associate), ... 1877.

Brown University, Providence, R. I.

BATES, PUTNAM, A., E.E., ... 1897.

39 Cortlandt St. and 113 W. 72d Street, New York City.

Engineering designer and draughtsman, with Crocker-Wheeler Company, from graduation to January 1, 1898; Erecting Engineer with same company until March 15, 1899; Assistant Secretary of the Crocker-Wheeler Company to date.

BAUMANN, A. P., E.M., ... 1899.

228 East 52d Street, New York City.

BAXTER, GEO. S., A.B., E.M., ... 1868.

18 Wall Street, New York City.

1878-79, Civil and Mining Engineer. 1880, Cashier N. P. R. R. 1890-95, Treasurer, N. P. R. R. 1895 to date, in lumber and railroad business.

BAYLES, FREDERICK P., E.M., ... 1895.

Steel Works, Pueblo, Colo., and 408 Main Street, Orange, N. J.

Chemist and Assayer for the Sonora Copper Co., Sonora, Old Mexico. First Assistant Chemist Steel Works of Colo., Fuel and Iron Co., 1897.

BEARD, JAMES THOM, E.M., C.E., ... 1877.

The International Correspondence School, 532 Webster Avenue, Scranton, Pa.

1879-80, Assistant Engineer, New York and Brooklyn Bridge. 1880–82. Assistant Engineer, C. B. & Q. R. R. 1882–83, Superintendent Smoky Hollow Mine, Avery, Ia. 1884–85, Assistant U. S. Dept. Min. Surveyor, Aspen, Colo. 1885-81, Engineer, Whitebreast Fuel Co., Ottumwa, Ia. 1891-92, Manager Miller Creek Land and Lime Co., Aspen, Colo. 1892–93, Secretary and Treasurer, Eldon Coal and Mining Co., Ottumwa, Ia. 1893–96, Iowa Mining Exchange, Ottumwa, Ia. 1892–94, wrote Beard's *Ventilation of Mines*, published by John Wiley & Sons, New York City. 1896, Chief Instructor in Mining Engineering International Correspondence School, Scranton, Pa. 1898, Principal of the School of Mines International Correspondence Schools, Scranton, Pa.

BEATTY, ALFRED CHESTER, E.M., ... 1898.

3 East 9th Street, New York City.

BECK, OSCAR CHARLES, ... 1899.

Assistant Chemist Taylor Iron and Steel Co., High Bridge, N. J., and 470 2d Street, Brooklyn, N. Y.

BECHSTEIN, CHAS. A., ... 1888.

Hotel Bresford, 2 W. 82d Street, New York City.

BEEBE, ALFRED L., PH.B., ... 1880.

Care of Gen. Chas. F. Beebe, Portland, Oregon.

1880–87, inclusive, Private Assistant to Prof. Ricketts, School of Mines, New York, in general analytical work, especially Mineral Analyses. Also Assistant in Assaying and Fellow in Chemistry, in 1881–87, inclusive. 1888–92, Assistant Chemist, New York Health Department. Since September, 1892, Bacteriologist, New York Health Department. 1898, traveling in the West.

BEHRMAN, GEORGE WILLIAM, C.E., ... 1893.

143 Rutledge Street, Brooklyn, N. Y.

November, 1893, to January, 1894, Transitman and Draughtsman, with the Raub Locomotive Works and Land Improvement Company.

BELLINGER, HIRAM PAULDING, C.E., ... 1887.

Solvay Process Company and 1902 W. Genesee Street, Syracuse, N. Y.

BENEDICT, WILLIAM DE LIESSELINE, E.M., . . . 1874.

Bank of Commerce Building, 31 Nassau Street, New York City, and 282 Vanderbilt Avenue, Brooklyn, N. Y.

1878–80, Assistant Superintendent and Superintendent, Revere Concentrating Co., Utah. 1880–81, Assistant Superintendent, Germania Smelting & Refining Co., Utah. In 1882, opened an office in New York City, as Consulting Mining Engineer and Metallurgist, and have since been engaged in examining and reporting on Mines in the United States, Ontario, Quebec, British Columbia, Mexico and England.

BENOLIEL, SOL. D., E.E., ... 1896.

Adelphi College, Brooklyn, N. Y.

BENJAMIN, MARCUS, PH.B., A.M. (Lafayette 1888), PH.D. (Univ. Nashville, 1889) (Life Member), . 1878.

U. S. National Museum, and 1710 N Street, N. W., Washington, D. C.

1878–82, with E. B. Benjamin, dealer in Chemical Apparatus. 1882, Editor *American Pharmacist*. 1883, Editor *Weekly Drug News*. May, 1883, to June, 1885, Chemist, U. S. Laboratory, New York. 1884–86, Lecturer on Chemistry, N. Y. Woman's Medical College and Hospital for Women. 1885, Sanitary Engineer N. Y. Board of Health. 1886–89, Editorial Staff, Appleton's *Cyclopædia of American Biography*. 1890, Editorial Staff, *Engineering and Mining Journal*. 1891–94, Editorial Staff in charge of Chemistry, *Standard Dictionary*. 1894–95, Editorial Work for D. Appleton & Co. 1895, Editorial Staff, *Johnson's Universal Cyclopædia*, New York. 1895–96, at the Smithsonian Institution, and since April, 1896, Editor U. S. National Museum, Washington, D. C. At various times on editorial staff of *Scientific American*, 1883–89; *Independent Oil Journal*,

1886; and on technical subjects in *New York Daily News*, 1886–95, *New York Star*, 1890–91; and *Pharmaceutical Record*, 1891; also of *Appleton's Annual Cyclopædia* since 1883. Other work includes translations of Berthelot's lectures on "Explosive Materials" (New York, 1883); authorship of Druggist's Circular, Prize Essay on "Disinfectants," 1885; authorship of chapters on *Mineral Paints* in "Mineral Resources of the United States," for years 1884–86, and other non-technical works. Organized the Corresponding Chapter of Chemistry of the Agassiz Association in 1892 and its President till 1896. Life fellow of the London Chemical Society and of the American Association for the Advancement of Science, of which he was elected a Vice-President, 1898, presiding over the "section on Social and Economic Science"; Member of Society of Chemical Industry, London, and of American Chemical Society, Member of International Jury of Awards, World's Fair, Chicago, 1893. Member of Assay Commission in 1896, Member of Jury of Awards, Tennessee Centennial Exposition, Nashville, Tenn., 1897. Member of Jury of Awards Trans-Mississippi and International Exposition, Omaha, Neb., 1898.

BENNETT, GEO. L., C.E., ... 1898.

U. S. Inspector Dr. Kershaw, P. O. Box 72, Harwich, R. I.

BERGER, JOHN, B.S. (C. C. N. Y. 1897), C.E., . . 1899.

Care of Shanly & Ryan, contractors for N. Y. Anchorage New E. R. Bridge, 26 Tompkins Street, and *for mail* 357 East 4th Street, New York City, N. Y.

BERRY, WILTON GUERNSEY, PH.B., ... 1886.

U. S. Laboratory Appraisers Stores and 329 W. 83d Street, New York City.

1886–89, Universities of Berlin and Heidelberg and General Chemical Research. 1889, to date, Assistant Chemist, New York Health Department. Health Department New York City. 1897–1899, Sec. & Treas. Asepta Chemical Co., New York City. 1899 Chemist in U. S. Laboratory, N. Y. City.

BERRY, GEORGE, C.E., ... 1888.

Assistant Engineer Department of Street Improvements, 23d and 24th Wards, 177th Street and 3d Avenue, New York City, and 78 Morton Street, Brooklyn, N. Y.

BETTS, ROMEO T., C.E., ... 1890.

Wallabout Basin, and 863 Jefferson Avenue, Brooklyn, N. Y.

BIEN, JOSEPH RUDOLPH, E.M., ... 1887.

140 6th Avenue, and 321 West 57th Street, New York City, N. Y.

1887–88, Topographer, U. S. Geological Survey, Survey of Geyser Basin, Yellowstone National Park. 1888–90, Practice as Civil and Mining Engineer, firm of Vermeule & Bien, New York City. 1890–91, Practice as Civil and Topographical Engineer alone, New York City. At present, Secretary Julius Bien & Co., Lithographers, Engineers and Geographical Publishers.

BINION, JOSHUA, B.S., C.E., ... 1895.

331 East 84th Street, New York City.

Summer of 1893, Volunteer Assistant, New York Speedway. 1895, Assistant

Summer School of Surveying, Columbia University. October, 1895, to November, 1897, Rodman, Draughtsman and Transitman, C. R. R. of N. J. November, 1897, Topographical Draughtsman, Department of Highways, New York City.

BISHOP, R. R., E.E., ... 1897.

American Telephone and Telegraph Co., 15 Dey Street, and 311 West 54th Street, New York City.

August, 1897, to May, 1898, with Chas. L. Eidlitz, Electrical Engineer and Contractor at 1133 Broadway, New York City. May, 1898, to date, with American Telephone and Telegraph Co. in operating department at 18 Cortlandt Street, New York City. December 1, 1898, made Assistant Chief Operator at New York office of A. T. & T. Co.

BLACK, ADOLPH, C.E., ... 1894.

Columbia University, and 1 West 118th Street, New York City.

Assistant Instructor, Summer School of Surveying, Summers 1893–97, inclusive. Assistant in Civil Engineering, Columbia College, 1894–96. State Inspector, New York State Tenement House Commission, 1894. Tutor in Civil Engineering, 1896–98. Instructor in Mathematics and Mechanical Drawing, Y. M. C. A., 23d Street Branch, New York City, 1893–95. Sanitary Inspector, Department Public Parks, 1895. Architect for Department Public Works, New York City, 1896–97.

BLAKE, EDWIN MORTIMER, E.M., PH.D. (1893), . 1890.

Instructor in Mathematics, Purdue University, Lafayette, Ind., also 230 Washington Avenue, Brooklyn, N. Y.

BLEECKER, C. P., ... 1881.

Care of R. G. Packard Co., 130 Pearl Street, and 117 Newman Avenue, Bayonne, N. J.

BLOSSOM, FRANCIS, C.E., ... 1891.

Sanderson & Porter, 31 Nassau Street, New York City, and 440 Henry Street, Brooklyn, N. Y.

1891–92, Engineer with C. W. Hunt Company. 1892, Assistant Engineer Equity Gas Works Construction Company. 1893–1899, Westinghouse, Church Kerr & Company. 1899, to date, Member of Firm of Sanderson & Porter, Engineers and Contractors.

BODELSEN, OSCAR, E.M., ... 1884.

Cons. Gas Co., Foot West 44th Street, New York City, and Pocantico Hills, N. Y.

BOECKLIN, WERNER, JR., C.E., ... 1891.

147 Cedar Street, New York City, N. Y.

January to May, 1893, ran level on preliminary (150 miles), H. & E. Extension, C. O. & S. W. Railway, in charge of all profiles and estimates under Chief Engineer. 1894, Inspector for Massachusetts Highway Commission on State Highway. Assistant Engineer in charge of erection of Stone Crushing Plant at Rock Hill, N. J., 1895. 1896, in Chief Engineer's Office Pa. Company, Pittsburg, Pa. July, 1897, to June, 1899, in Private Practice, Surveys, Designs for Sand Filteration Plant, Patent Canal Lock Gates, and Coal Handling Plants. Also Engineer

on Design for development of League Island Park (300 acres), Phila., for Woodside Park same City and for numerous Private Estates. June, 1899, to date, Engineer for Robin's Conveying Belt Co., New York.

BŒRNER, EMILE C., JR., E.E., ... 1897.
Galvanic Metal Paper Company, 725 Broadway, and 444 Lexington Ave., New York City, N. Y.

June to October, 1897, Assistant Mechanical Engineer and Draughtsman with Port Chester Bolt and Nut Company. October, 1897, to March, 1899, Assistant Engineer of Tests in Mechanical Engineering Department of Solvay Process Company, Syracuse, N. Y. September, 1899, to date, Chief Engineer for Galvanic Metal Paper Co.

BOGERT, MARSTON T., PH.B., A.B., ... 1894.
Havemeyer Hall, Columbia University, New York City, and 259 Broadway, Flushing, Queens County, L. I., N. Y.

Awarded University Fellowship in Chemistry for 1895, but resigned to accept position of Assistant in Organic Chemistry. Assistant in Organic Chemistry, Columbia University, 1894-97, and Tutor in same, July 1 to October 15, 1897. Instructor in same from October 15, 1897, to date. Librarian American Chemical Society, 1898-99.

BOOK, DWIGHT DANA, C.E., E.E. (1892), . . . 1890.
159 Washington Park, Brooklyn, N. Y.

BOOKMAN, S. (Associate), PH.D., M.A., . . . 1891.
1 Madison Avenue, and 9 East 62d Street, New York City.

Associate in Physiological Chemistry, Pathological Institute, New York State Hospitals.

BOORÆM, ROBERT ELMER, E.M. (Life Member), . . 1888.
2 East 15th Street, New York City.

1879, Assayer, general work in Leadville, Colorado. 1880-87, Assistant Superintendent, afterward manager, Evening Star Mining Co., Morning Star Consolidated Mining Co. and others at Leadville, Colorado, Lead-silver Mines. Also in charge Farwell Con. M. Co., Gold Mines at Independence, Colorado. 1887-90, General Manager Blue Bird Mining Co., Ltd., Butte, Montana, Operating 90-Stamp Mill, Dry Crushing, Chloridizing, Amalgamating Process. 1891, General Consulting Mining Engineer, and Consulting Director in Gold, Silver and Lead-Mining Companies, of which a specialty is made. Also Mine Operator and owner, Silver Mines at Aspen, Colorado, and Consulting Engineer.

BOYD, RICHARD CHARLES, PH.B., A.M. (1892), . . 1891.
115 West 71st Street, New York City.

BRADLEY, STEPHEN ROWE, JR., PH.B., . . . 1890.
Orangeburg and Nyack, N. Y.

July, 1891, to 1894, Secretary and Treasurer Union Electric Co., January, 1894, Secretary and Treasurer, The Arlington Manufacturing Co., New York City.

BRASCHI, VICTOR MANUEL, PH.B., E.M., C.E., . . 1881.
Apartado 830, City of Mexico, Mexico.

June, 1884, to October, 1884, Inspector of New York Tenement House Com-

mission. October, 1884, to May, 1885, Interpreter and Secretary to Chilian Governor's Commissioner sent to visit and report on American Mining and Smelting. May, 1883, to October, 1885, employed by Rend Rock Powder Co. in Flood Rock Explosion Work. October, 1885, to January, 1889, Assistant Consulting Engineer and in charge of Foreign Business, Rand Drill Co. January, February March, 1889, Reporting on Mines in Mexico for above Co., and for three years, from April, 1890, to April, 1893, engaged in introducing Rand Rock Drilling Machinery in Mexican Mines. In April, 1893, arranged to open a General Mining Machinery and Supply business, in the City of Mexico, in which I am at present engaged. Agent for Mexico for Fraser & Chalmers, Rand Drill Co., John S. Robeling & Sons and Repanno Chemical Co.

BRERETON, THOMAS J., A.B., 1879, C.E., . . . 1883.
Engineer Cumberland Valley Railroad, Chambersburg, Pa.

1879, Rodman on Location of Redstone Br. P. R. R. 1880 and 1882 (Summers) on New York State Geodetic Survey of Adirondacks. 1883–85, Leveling P. R. R. Clearfield Co. Surveys and Construction. On Corps of Engr. M. of W. P. R. 1888–89, Assistant Supervisor P. R. R. 1890–92, Supervisor Tyrone Div., P. R. R. 1893, Engineer Cumberland Valley Railway.

BREWSTER, HENRY DRAPES (Associate), . . . 1883.
Care Brewster & Co., 47th Street and Broadway, New York City.

BRINLEY, JOHN ROWLETT, C.E., ... 1884.
Morristown, N. J. and 1 Union Square, New York, N. Y.

1884-88, Department of Public Works, New York City. 1888 to date, Civil and Landscape Engineer.

BRITTON, NATHANIEL LORD, E.M., PH.D., . . . 1879.
Suburban Street near Perry Avenue, Bedford Park, N. Y.

Assistant of Geology, School of Mines, 1879–1887. Instructor in Botany, Columbia University, 1887–1890. Adjunct Professor of Botany, Columbia University, 1890–1891. Assistant Geological Survey of New Jersey, 1880–1887. Botanist, Geological Survey of New Jersey, 1881, 1890. Field Assistant, U. S. Geological Survey, 1882. Professor of Botany, 1891. Specialty—Systematic Botany. Director-in-Chief New York Botanic Garden.

BROWN, ROBERT GILMAN, E.M., ... 1889.
Standard Consolidated Mining Co., Bodie, Cal.

BUCK, VICTOR BUCHANAN, JR., MET.E., . . . 1894.
The Towers, 1 West 94th Street, New York City.

BUCKLEY, CHARLES RAMSAY, A.B., A.M., E.M., . 1877.
29 Broadway, New York City.

BURDEN, HENRY 2d, A.B., PH.B., ... 1892.
Cazenovia, N. Y.

BURNS, ABRAHAM LINCOLN, E.M., ... 1887.
Erecting Engineer, Jabez Burns & Sons, 542 Greenwich Street, and 501 West 113th Street, New York City.

Since November, 1887, with Messrs. Jabez Burns & Sons (Millwrights and Ma-

chinists and Manufacturers of Patented Machines for Treating Coffee and Spices). July, 1880, 1897, Member of the firm Track, Burns & Co. Professional work has been general shop draughting and machine design, and arranging machines and power transmission in coffee establishments.

BURNS, ELMER Z., E.M., ... 1887.
Niagara Falls, N. Y.

1887–88, Engineer and Chemist for the Pittsburg and Lake Angeline Iron Co. 1889–90, Assistant Electrician for the United States Electric Light Company. 1890-91, Assistant Electrician for the Mather Electric Company. 1891-93, City Engineer of Niagara Falls and Consulting Engineer for the Lewiston and Youngstown R. R. Company, for the North Tonawanda Street Railroad Company, and for the Niagara Falls and Suspension Bridge Railroad Company.

BURNS, WM. G., E.E., ... 1898.
423 West 117th Street, New York City,

Since August, 1898, with New York Telephone Co.

BUTLER, WILLARD PARKER, E.M., LL.B. (Life Member), 1878.
Counsel in Patent Cases, 59 Wall Street, and 143 East 36th Street, New York City.

C.

CABOT, JOHN, JR., E.M., ... 1899.
126 W. 48th Street, New York City.

CAIRNES, FRED. I., Met.E., ... 1890.
Supt. Bridgeport Copper Co., and 246 Park Avenue, Bridgeport, Conn.

1890–92, in charge of surveying party in Tennessee. 1892-93, Superintendent Mines, Ducktown, Tenn. 1893-97, Metallurgist Bridgeport Copper Co. 1897, to date, Superintendent Bridgeport Copper Co.

CALMAN, ALBERT, PH.B., PH.D., ... 1882.
7 West 75th Street, New York City.

CANFIELD, FREDERICK A., A.B., A.M., E.M., . . . 1873.
Mining Engineer, Dover, N. J.

CARSON, JAMES PETTIGRU, E.M., ... 1868.
Oakley, South Carolina.

CARTER, B. P., E.M., ... 1895.
P. O. Box 1056, Johannesburg, S. A. R.

December, 1896, to 1897, Surveyor and Assayer of the Crown Deep, Ltd. 1897-99 in charge of Surveying and Smelting, Crown Deep Mine, Ltd.

CASAMAJOR, GEORGE H., C.E., ... 1892.
Asst. Editor Cosmopolitan Magazine, Irvington-on-Hudson, N. Y.

1892 to May, 1893, with the *Railroad Gazette*, N. Y. May to September, 1893, with C. B. Brush, Hoboken, N. J., as Transitman, Levelman, etc. October, 1893, to January, 1896, with the East River Gas Company, N. Y. February to May,

1896, Engineer Inspector D. P. W., N. Y. May, 1896, to January, 1898, a partner in the Bacheller Newspaper Syndicate, occupied in literary and editorial work. January, 1898, to date, Assistant Editor *Cosmopolitan Magazine.*

CASEY, EDWARD PEARCE, C.E., PH.B. (1888), . . 1886.
Architect, 171 Broadway and The Alpine, 55 West Thirty-third Street, New York City.

With McKim, Mead & White, Architects, New York City, until January, 1890. Abroad, and Student in L'Ecole National des Beaux Arts Paris from February, 1890, until September, 1893. Five mentions in Architecture, and a medal in Modeling. At present Architecture, 171 Broadway, New York City. Architect for the completion of the Congressional Library Building, Washington, D. C., from 1892 to 1897. Vice-President of the Blank Arts Society of Architects 1896, to date. Fellow of the American Institute of Architects in 1897.

CASWELL, KENNETH L., B.S., ... 1898.
114 East 31st Street, New York City.

CAULDWELL, JOHN BRITTON, C.E., ... 1877.
Director Fine Arts, U. S. Commission to Paris Exposition, 20 Rofp, Paris, France.

CHANNING, JOHN PARKE, E.M., ... 1883.
34 Park Place, New York City.

1893, Chemist Hudson River, O. and I. Co. 1884, with S. E. Cleaves & Son, Manufacturers of Mining Machinery, Houghton, Mich. 1884-95, Assistant Mining Engineer Tamarack Mine, Calumet, Mich., Dep. Com. Mineral Statistics, Michigan. 1885-86, Superintendent Honduras Land and Navigation Co. 1886-87, Exploring for iron on the Gogebic Range, and Mining Engineer for Milwaukee, L. S. and Western Railway, Superintendent Iron Belt Mine. 1887-90, Inspector of Mines, Gogebic Co., Mich. 1890-92, Superintendent East New York Iron Co., Ishpeming, Mich. 1892-93, Superintendent Iron Exploration Co., C. M. and St. P. Railway. Assistant to General Manager Calumet and Hecla Mining Co., 1894, Consulting Work, 1894, to date.

CHESTER, ALBERT HUNTINGTON, A.M., E.M., SC.D., PH.D., 1868.
Professor of Chemistry and Mineralogy, Rutgers College, and 11 Union Street, New Brunswick, N. J.

Professor of Chemistry at Hamilton College from 1870 and Mineralogy from 1873 to 1891. Conducted the Analytical Laboratory there from 1871. Chemist New York State Board of Health, 1882. Examined and reported on mines of iron, gold, silver, lead and zinc, in Michigan, Minnesota, Ontario, Arkansas, Colorado, Utah, Nevada, California and Nova Scotia. Analytical work has been largely in two lines, viz., for iron-blast furnaces and of paints and varnishes. Field work has been, a great part of it, in the iron mines of Minnesota and the gold mines of Colorado. Now engaged in chemical work for the State Geological Survey of New Jersey and have charge of its mineral collections.

CHIBAS, LOUIS F., E.M., ... 1898.
Guantanamo, Cuba.

CHURCH, ELIHU DWIGHT, JR., E.M., ... 1887.

Secretary Church & Dwight Co., 63–65 Wall Street, New York, N. Y., and 286 Clinton Avenue, Brooklyn, N. Y.

1887–88, Fellow Qualitative Analysis School of Mines. 1888–89, Assistant Superintendent of Lead Mine and Concentrating Works. 1889–91, with Church & Co., in charge of experiment plant. 1896, with Church & Co., Trenton, Mich.

CHURCH, JOHN ADAMS, A.M., E.M., PH.D., . . 1867.

Corn Exchange Building, 11 William Street, and 1350 Madison Avenue, New York City, Cable Address Scotist, N. Y.

CLARK, ALLAN J., E.M., ... 1896.

Homestake Mining Co., Lead, S. D., and care B. S. Clark, Box 1580, New York City.

1896 to May, 1897, Assistant Engineer T. C. I. & R. R. Co., Blocton, Ala. May, 1897, to date, Assayer Homestake Mining Co., Lead, South Dakota.

CLARK, CHAS. MARTIN, E.E., ... 1897.

Clark & MacMullen, Engineers, 42 East 23d Street, New York City, and 171 Lefferts Place, Brooklyn, N. Y.

CLARK, DIEGO LOMBILLO, C.E., ... 1890.

Cardenas, Cuba.

CLARK, EDMUND (Associate), ... 1892.

Chemical Laboratory, Health Dept., Criminal Court Bldg., Centre and Franklin Streets, New York City and 105 Beech Street, Flushing, L. I., N. Y.

From August, 1892, to August, 1895, Assistant Chemist, Homestead Steel Works, Carnegie Steel Co., Pittsburg, Pa. Since August 1, 1895, Assistant Chemist, Health Department, New York City.

CLARK, EDWIN PERRY, E.M., ... 1880.

Title Guarantee and Trust Co., 175 Remsen Street, and 396 Fourth Street, Brooklyn, N. Y.

1880–83, Engineer and Surveyor for Silver-Cord Combination, and Robert E. Lee Mining Companies, Leadville, Colo. 1883–84, medical student. 1884 to date, Assistant Superintendent and afterwards Superintendent Title Guarantee and Trust Company, 55 Liberty Street, New York, and 26 Court Street, Brooklyn. In charge of construction and maintenance of locality-indexes of Real Estate Records of New York, Kings and Westchester counties, N. Y.

CLARK, GEORGE HALLETT, C.E., ... 1893.

Asst. Engr. Dept. Highways, Bronx, and The Monticello, 406 West End Avenue, New York City.

1893–94, Transitman Metropolitan Traction Co., Lexington Avenue Cable Construction. Assistant Engineer in charge construction Lexington Avenue Cable Road. Assistant Engineer D. D. I., from June 1, 1896, to date.

CLARK, JOSIAH HUNTOON, E.M., ... 1892.

228 Broadway, Paterson, N. J.

1897–98, with National Mexican Mining and Developing Co., as Engineer and

Surveyor, located at El Plomo, Sonora, Mexico. January to April, 1899, Assistant in Examination of Mines in Vera Cruz, Mexico. April, 1899, to date, Chemist Mexican Copper Co., Ramos, San Luis Potosi, Mexico.

CLARK, WILLIAM C., M.E., ... 1892.

Sterling I. and R. Y. Co., Sterlington, Rockland Co., N. Y.

COFFIN, TRISTRAM ROBERTS, C.E., ... 1898.

Care W. S. Fanshaw, 11 Pine Street and 258 West 72d Street, New York City.

COKEFAIR, FRANCIS A., C. E., ... 1894.

20 Broad Street, New York City, and 119 Crescent Avenue, Plainfield, N. J.

COLBY, ALBERT LADD, PH.B., ... 1881.

Metallurgical Engineer, The Bethlehem Steel Co., South Bethlehem, Pa.

1881–83, Assistant to Professor C. F. Chandler on New York State Board of Health Bureau of Chemical Analysts. 1883–89, Introduction in Quantitative Analysis and Chemical Philosophy in the Lehigh University, South Bethlehem, Pa. 1887–92, Head Chemist of the Bethlehem Iron Co. 1892, to date, Metallurgical Engineer same Company, South Bethlehem, Pa. Also July, 1897, Secretary and Treasurer Association of American Steel Manufacturers. Specialty, Metallurgy of Iron and Steel.

COLE, HAROLD MORRIS, E.M., C.E., ... 1887.

Care United S. and R. Co., East Helena, and 1045 North Warren Street, Helena, Montana.

COLTON, CHARLES ADAMS, E.M., ... 1873.

367 High Street, and 57 Broad Street, Newark, N. J.

1873–82, Assistant in Mineralogy, School of Mines, Columbia College, New York. 1882–84, Professor of Chemistry and Mineralogy, Rose Polytechnic Institute, Terre Haute, Indiana. 1884, to date, Director and Instructor in Chemistry and Physics, Newark Technical School.

CONANT, HENRY DUNNING, E.M., ... 1886.

Asst. Supt. the Lake Superior Smelting Co., Houghton, Mich.

1886–88, Assistant Engineer Tamarack and Osceola Mines, Lake Superior, and H. and C. R. R. 1888–89, Assistant Engineer on Preliminary of Northern Michigan Railroad. 1889, Assistant in Chief Engineer's Office, Buffalo and Geneva Railway. 1889–91, Assistant and Resident Engineer, Norfolk and Western Railroad, in charge of Preliminary Location and Construction. 1891, Engineer Coeburn Land and Improvement Co. 1893, Assistant Engineer, N. Y., N. H. & H. Ry. 1894, Assistant Engineer Playa de Oro Mining Co., Ecuador, S. A. 1895, Assistant Engineer Boston and Montana C. C. & S. M. Co. 1896–98, Manager Playa de Oro Mining Co., Playa Rica, Ecuador. 1898, Assistant Superintendent The Lake Superior Smelting Co., Mich.

CONGDON, ERNEST ARNOLD, PH.B., F.C.S., . . 1887.

Professor of Chemistry, Drexel Institute Arts, Science, and Industry, and University Club, Philadelphia, Pa.

1887–89, Chemist to Champlain Fibre Co., Willsborough, New York. 1889, Studied at the University of Berlin, Summer Semester. 1889, to date, Instructor in Qualitative Analysis and Assaying at the Lehigh University. 1891, Professor of Chemistry in the Drexel Institute of Arts, Sciences and Industries, Philadelphia, Pa.

CONOVER, JOHN T., E.E., ... 1898.
49 West 69th Street, New York City.

COOPER, WILLIAM HAMILTON, PH.B. (Life Member), . 1882.
Address unknown.

CORNWALL, HENRY BEDINGER, A.B., A.M., E.M., PH.D., 1867.
Professor Applied Chemistry and Mineralogy, Princeton University, and 51 Nassau Street, Princeton, N. J.

COX, JENNINGS STOCKTON, JR., MET. ENG., . . 1887.
General Manager Spanish Am. Iron Co., Santiago de Cuba, Island of Cuba, and 156 Meadow Street, New Rochelle, New York.

1887, Government Survey for Canal between Harlem and Hudson River. 1888–89, Homestead Steel Works, Draughtsman and afterward Assistant Master Mechanic. 1890, Inspected construction of Steamer "Sezurania" and "Vigilancia" for the U. S. and B. M. S. S. Co., at Roach's Shipyard, Chester, Pa. 1891, Reporter for same Company on Engineering matters along the Brazil coast. 1892, with same Company in New York. 1892, Assistant Superintendent Aurora Iron-Mining Company, Ironwood, Michigan. 1893, Assistant Superintendent Monte Christo Mining Co., Pride of the Mountain Mining Co., Rainy Mining Co., and United Concentration Company. 1894, Professional work in New York and Cuba. 1895, Agent Crocker-Wheeler Electric Co., Pittsburg, Pa.

COYKENDALL, EDWARD, C.E., ... 1895.
Rondout, N. Y.

COYKENDALL, FREDK., A.B., A.M., C.E., . . . 1897.
Secretary Cornell Steamboat Company, Foot West 52d Street and 1 West 72d Street, New York, N. Y.

CRAMER, STUART W., E.M. (Associate), . . . 1889.
Engineer and Contractor, Charlotte, N. C.

Graduate of the United States Naval Academy; resigned from the United States Navy, September, 1888. Graduate Student at School of Mines, 1888–89. Assayer in charge of the United States Assay Office, Charlotte, N. C., 1888–93. Special agent for collection of statistics on gold and silver for the Southern states, 1890. March 10, 1893, to November, 1895, Manager for the D. A. Tompkins Company, General Engineers and Contractors, of Charlotte, N. C. November, 1895, to the present time Contractor and Dealer in Cotton Mill Machinery and Equipment. Specialty: Complete contracts for new cotton mills and the reorganization of old plants.

CRAMPTON, S. H., E.E., ... 1897.
32 Gold Street, New York City, and 95 Gates Avenue, Brooklyn, N. Y.

Edison Electric Ill. Co., of New York. New York Telephone Co. Construction Department.

CROCKER, FRANCIS BACON, E.M., ... 1882.
Professor Electrical Engineering, Columbia University, and 14 West 45th Street, New York City.

1882-86, Electrical Engineer and Inventor. 1886-87, Vice-President and Electrician of "C. and C." Electric Motor Co. 1887-89, Vice-President and Electrician Crocker-Wheeler Electric Motor Co. 1889-92, Instructor in Electrical Engineering, School of Mines, Columbia University. 1892, Adj. Professor. 1893, Professor. President American Institute Electrical Engineers, June, 1897-98.

CUSHMAN, ALEXANDER RAMSEY, PH.B., PH.D., . . 1878.
128 East Sixteenth Street, New York City.

1878-80, Post Graduate study at the School of Mines, for degree of Ph. D. 1880-82, in Colorado, visiting mine and smelters. 1882-90, engaged in pursuing chemical studies and lecturing on geology. 1890 to July, 1897, Assistant Instructor in Qualitative Laboratory at the School of Mines, Columbia University.

D.

DALY, EDWIN HOWELL, E.E., ... 1898.
Edison Elec. Ill. Co. of N. Y., 55 Duane Street, and 1064 Madison Avenue, New York City.

DARWIN, HARRY GILBERT, C.E., ... 1887.
Special Agent, The Lappin Brake Shoe Co., 39-41 Cortlandt Street, New York City, and Glen Ridge, N. Y.

June, 1887, to October, 1887, Rodman and Leveler on Railroad field work in New York State. October, 1887, to May, 1888, Draughtsman Strong Locomotive Co., New York City. August, 1883, to Oct., 1894, Assistant Engineer, The Safety Car Heating and Lighting Co., New York City. Erection of special gas works, and equipment of railroad cars. With Pinsch gas and steam heating appliances, Oct., 1894 to Nov., 1899. P. Asst. Eng. S. C. H. L. Co. Nov., 1899, to date, Special Agent the Lappin Brake Shoe Co., New York.

DAVIS, CHARLES HENRY, C.E., ... 1887.
Room 306 Fidelity and Casualty Building, 99 Cedar Street, New York City and Bellevue Ave., Upper Montclair, N. J.

Expert Course and Thompson-Houston Electric Co., Lynn, Mass., summer 1887. Agent Lawer Mann Electric Co., winter 1887-88. Supt. selling and construction New York office S. M. Elec. Co., summer and winter 1888. Agent Westinghouse Electric Co., winter 1888. Consulting Supervising Electrical Engineer from May, 1889, to date.

DAVIS, JOHN WOODBRIDGE, C.E., PH.D., . . . 1878.
523 West 173d Street, New York City.

DAVIDSON, WILLIAM STEWART, E.M., . . . 1897.
Manager Machinery Department, Clarkson & Co., Vladivostock, Eastern Siberia, Russia, via Japan.

1897-98, Representing Rand Drill Co. in China and Japan. July, 1898, to date, Manager Machinery Department of Clarkson & Co., Vladivostock, Eastern Siberia.

DEGHUÉE, JOSEPH ALBERT, PH.B., A.M. (1892), PH.D. (1893), ... 1890.

Chemical Laboratory, Health Department, New York City, and 247 Harrison Street, Brooklyn, New York.

Assistant Demonstrator in Physics and Chemistry, College of Physicians and Surgeons, to March, 1896. March, 1896, to date, Assistant to Chemist, New York City Health Department.

DELFIELD, AUGUSTUS FLOYD, PH.D. (Associate), . 1899.

University Club, New York City.

DELUZE, LOUIS PHILIPPE, C.E., ... 1879.

DeLuze & Emmett, Engineers and Surveyors, P. O. Building, New Rochelle, N. Y.

DENTON, FREDERICK WARNER, C.E., ... 1889.

Superintendent of Winona Mine, Houghton, Mich.

1889-90, Fellow in Engineering, School of Mines. 1890-94, Professor of Mining and Civil Engineering, Michigan Mining School, and in general practice of engineering. 1894-95, Mining Engineer Minnesota Iron Co. 1895, to date, Professor of Mining, School of Mines, University of Minnesota. Secretary of the Lake Superior Mining Institute since its organization in 1893.

DERLETH, CHAS., JR., B.S., C.E., ... 1896.

Columbia University and 674 East 135th Street, New York City.

Assistant in Civil Engineering, 1896-99. Assistant in Litchfield Surveying School, 1896 and 1898. Assistant in Geodetic School, 1896-99. Summer, 1897, Transitman on Rapid Transit Surveys. Instructor in Mechanical Drawing, Algebra and Geometry, Y. M. C. A., 23d St. Branch, 1896-98. Instructor in Geometry and Trigonometry, East Side Evening High School, 1898-99. From 1897-99, Assistant to Prof. Burr in the design of the City Island Bridge. At present Assistant to Prof. Burr and Lecturer in Civil Engineering Dept., Columbia University.

DETWILLER, CHAS. HENRY, PH.B., ... 1885.

Detwiller & Melendy, Architects, 97 Nassau Street, New York City and *for mail* 56 Danforth Avenue, Jersey City, N. J.

1885-88, studying in architect's office in New York and traveling in Europe. 1888-92, Practicing Architect in Jersey City. 1892 to date, Practicing Architect in New York City.

DEVEREUX, WALTER BOURCHIER, A.B., A.M., E.M., . 1878.

Care of Ledoux & Co., 98 John Street, New York City and Glenwood Springs, Colo.

DICKERSON, F. SECOR, E.E., ... 1899.

Great Neck, L. I., N. Y.

DOBBINS, MAX. E.M., ... 1895.

Present address unknown. If any member knows his address please advise the Secretary of it.

DODGE, FRANK DESPARD, PH.B., PH.D., . . . 1888.

Dodge & Olcott, 137 Water Street, and 111 Montague Street, Brooklyn, N. Y.

From October, 1891, to date, Chemist, with Dodge & Olcott, manufacturers of essential oils, etc. 1888-90, Fellow in Chemistry, Assistant in Organic Laboratory School of Mines. 1890-91, studying in Germany.

DOLAN, CHARLES FRANCIS, C.E., ... 1892.

Dept. of Bridges, Park Row Building, and 697 East 135th Street, New York City.

1892-93, United States Inspector of Dredging Operations, Harlem Ship Canal and Newtown Creek. 1893, to date, with Department of Street Improvements, New York City. 1894, with U. S. Engineers on New York Harbor Improvements. 1895, Bridge Shop Practice and October. 1895, to date, with Department of Public Works, New York, N. Y.

DOUGLAS, JOHN SHEAFE, C.E., ... 1890.

Columbia Electrical Supply Co., 93 Liberty Street, and the Rockingham, 56th Street and Broadway, New York City.

1890, Course Electrical Engineering, Columbia College. 1891, Crocker-Wheeler Electric Motor Company. 1892, Assistant Engineer Western Electric Company in Lighting Department. 1893, Superintendent of Union Elect. Co.'s Exhibit at World's Columbian Exposition, Chicago. 1895, Secretary and Treasurer Chapin, Douglas Elec. Co. 1896, Columbia Electrical Supply Co, 329 Fourth Avenue, New York City.

DOUGLAS, EDWARD MOREHOUSE, C.E., . . . 1881.

Topographer U. S. Geol. Survey, and Takoma Park, Washington, D. C.

1897, Geographer U. S. Geological Survey.

DOW, ALLAN WADE, PH.B. (Life Member), . . 1888.

Office of the Engineer Commission, District of Columbia, and 2016 Hillyer Place, Washington, D. C.

1888-89, Honorary Fellow Quant. Laboratory, School of Mines. 1889, Chemist at Tilly Foster Mine, New York. 1889-94, Assistant Chemist of The Barber Asphalt Paving Co. 1894, District Chemist, Inspector Asphalt Cement and Building Stones, District of Columbia.

DOWNS, WILLIAM FLETCHER, E.M., ... 1882.

Joseph Dixon Crucible Co., and 75 Fairview Avenue, Jersey City, New Jersey.

With the Joseph Dixon Crucible Co., since graduation. From June, 1882, to September, 1882, at experiment work. From September, 1882, to October, 1884, in charge of lubricating department. From October, 1884, to present time, Superintendent of crucible and other departments.

DRASEL, CHARLES, E.M., ... 1895.

56 Bowers Street, Jersey City, N. J.

From October, 1896, to February, 1897 Mining Engineer and Surveyor. February, 1897, to January, 1898, Assistant Metallurgist and in charge of both blast

furnaces and converting plants of the Mazapil Copper Co., of Concepcion del Oro-Zacatecas, Mexico.

DRESSER, DANIEL LEROY, C.E., ... 1889.

574 Broadway, New York City, and Oyster Bay, L. I., N. Y.

DRUMMOND, ISAAC WYMAN, E.M., PH.D., ... 1878.

F. W. Devoe & Co., William and Fulton Streets, New York City.

DUFOURCQ, EDWARD LEONCE, E.M., ... 1892.

Olcott, Fearn & Peele, 18 Broadway, and 2 West 83d Street, New York City.

1892-93, Assistant Superintendent Costa Rica Pacific Gold Mining Company. Punta Arenas, Costa Rica. Summer of 1893, Assistant in Mining, Columbia College and Transitman for J. F. Carey & Co., Brooklyn. November, 1893, Assistant Engineer, Mazapil Copper Company, Concepcion del Oro, Zacatecas, Mexico, and Assistant Engineer Coahuila and Zacatecas Railroad. December, 1894, to November, 1896, Superintendent of International Mining Co., San Miguel del Mezquital, Mexico. November and December, 1896, Assistant Manager Mining Department, Cons. Kansas City Smelting and Refining Company, El Paso, Texas, Jan., 1897, to Aug., 1898, Superintendent of Mines, same Company at Sierra Mojada, Mexico. Sept., 1898, entered firm of Olcott, Fearn & Peele, Consulting Engineers, New York City.

DUNHAM, EDWARD KELLOGG, PH.B., ... 1881.

338 East Twenty-sixth Street, New York City.

Professor of Pathology, Bacteriology and Hygiene in Bellevue Hospital Medical College, New York City.

DURHAM, H. W., C.E., ... 1895.

Greytown, Nicaragua, and 162 W. 27th Street, New York City.

Draughtsman Rapid Transit Commission, June to December, 1895. Field Assistant U. S. Geological Survey, May, 1896-97. 1897 to 1899, member of the permanent staff of Wm. Barclay Parsons, C.E., and now (Oct., 1898) temporarily engaged on surveys for the Nicaragua Canal by the Department of State. Dec., 1899, to date, with the Isthmian Canal Commission.

DUSENBERRY, WALTER LORTON, M.E., ... 1884.

220 Tenth Street, South Brooklyn, N. Y.

1884-87, miscellaneous. U. S. Coast Survey. Mining in Mexico and the West. Survey of New Parks, Westchester County, etc. 1887-89, Inspector of Masonry and Transitman on New Croton Aqueduct. 1889-91, in charge of party and Assistant Engineer of Construction, Department of Public Parks, New York City.

DWIGHT, ARTHUR SMITH, E.M., ... 1885.

Cons. Kansas City Smelting and Refining Co., Argentine, Kansas.

1885, Assistant Assayer at works of The Colorado Smelting Company, Pueblo, Colorado. 1885-88, Assistant Chemist and Chemist, except autumn of 1886, when examining and reporting on lead deposits of Cœur d'Alene region, Idaho Territory, and spring of 1889, when acting as Assistant Superintendent Madonna Mine, Monarch, Colorado. 1889-90, Metallurgist, and up to date, General Superintendent of the Colorado Smelting Co. December, 1896, to date, General

Superintendent Cons. K. C. Smelting and Refining Co., in charge of Operating Department of all plants of that company in United States and Mexico.

E.

EASTWICK, GEORGE SPENCER, C.E., ... 1879.
Buckingham Hotel, New York City.

EBERHARDT, WILLIAM G., E.M., ... 1891.
450 West Twenty-second Street, New York City.

1891-93, General Engineering and Draughting. March, 1893, to May, 1894, Assistant Superintendent and Assayer Powhatan Land and Mining Co., Va. 1894-95, Assayer and Surveyor Mazapil Copper Co., Zacatecas, Mexico. 1896, Professional work in New York and New Jersey. April, 1897, to date, with Ricketts & Banks, as expert in ore testing and in the field.

ECKERSON, CHAS. H., E.M., ... 1898.
Closter, Bergen Co., N. J.

University Scholarship in Geology for year 1898-99. Instr. in Mining, Univ. of Minnesota. Minneapolis, Minn.

EDWARDS, RICHARD MASON, E.M., ... 1886.
Red Jacket and Houghton, Mich.

1886-87, General Assay office at Houghton, Mich. 1888-89. Professor of Mining, Michigan Mining School, Houghton. 1890, to date, Mining Engineer for Tamarack, Tamarack, Jr., Osceola and Kearsarge Mining Cos., L. S., Mich.

EILERS, KARL EMRICH, E.M., ... 1889.
Superintendent Colorado Smelting Co., Pueblo, Colo.

1889-91, student and traveling in Europe. 1895-96, Assistant Superintendent Colorado Smelting Co., Pueblo, Col. 1896, Kansas City, S. & R. Co., El Paso, Texas. 1897, to date, Superintendent Colo. S. & R. Co., Pueblo, Colo.

ELLIOTT, ARTHUR HENRY, PH.B., PH.D., ... 1881.
4 Irving Place, New York City, and Home Park, New Rochelle, N. Y.

Professor Chemistry and Physics, New York College of Pharmacy. Chemist to Consolidated Gas Co. Editor Anthony's *Photographic Bulletin*. Author A. H. Elliott's Qualitative Chemical Analysis.

ELLIOTT, WILLIAM, PH.B., ... 1880.
56 Wall Street, New York City.

EMANUEL, L. V., C.E., ... 1896.
Minas Jesus Maria, Mineral die Carmen, Durango, Mexico.

1898, Assistant to Superintendent, Assayer and Cashier, Las Minas De Cobre de Tepezala, Tepezala, Aguascalientes, Mexico.

ENGEL, LOUIS GEORGE, E.M., ... 1880.
New York Sugar Refining Co., L. I. City, and *for mail* 142 Ross Street, Brooklyn, N. Y.

Three years, Tilly Foster Iron Mine (E. M.). Thirteen years, Brooklyn Sugar Refinery. Three years N. Y. Sugar Refining Co.

ENGELHARDT, EUGENE NICHOLAS, E.M., ... 1885.
Selby, Contra Costa Co., Cal.

1886, Assayer, Chemist and Assistant Superintendent Pueblo Smelting and Refining Co. 1887 and 1888, Superintendent of the same company. 1889, Assistant Superintendent Anaconda Smelting Co. From 1890 and to present time, Assistant Superintendent Selby Smelting and Lead Co.

EVANS, I. N., C.E., ... 1895.
Evans, Almirall & Co., 623 John Hancock Bldg., Boston, Mass.

F.

FAHYS, GEORGE ERNEST, C.E., ... 1884.
54 Maiden Lane, and 310 West Seventy-third Street, New York City.

Vice-Prest. Fahys Watch Case Co. since 1888. Prest. Brooklyn Watch Case Co. since 1893. Prest. Alvin Mfg. Co. since 1896. Vice-Prest. Montauk Steamboat Co., 1893-99. Treas. Sag Harbor Water Co. since 1893. Vice-Prest. Jewellers' Assn. and Board of Trade.

FEARN, PERCY LEROY, E.M., ... 1889.
18 Broadway, N. Y.

1889–90, Assayer and Surveyor, Trinidad Mine, Costa Rica. 1890–92, Superintendent Trinidad Mine, Costa Rica. 1892-93, Consulting Mining Engineer, Illinois Fluor Spar and Lead Co. 1893-94, Vice-President of above. 1894–96, engaged in examining and reporting on Mines in Western States and Mexico. 1896, entered firm of Olcott, Fearn & Peele, 18 Broadway, New York.

FERGUSON, GEORGE ALBERT, PH.B., ... 1890.
115–119 West Sixty-eighth Street, New York City, and 303 Stuyvesant Avenue, Brooklyn, N. Y.

FERGUSON, WILLIAM CUSHMAN AUGUSTINE, PH.B., . 1887.
Laurel Hill Chemical Works, Laurel Hill, New Jersey, and 40 North Parsons Avenue, Flushing, L. I., N. Y.

Chief Chemist Nichols Chemical Co. Consulting Chemist General Chemical Co. Professor of Analytical Chemistry and Mathematics, College of Pharmacy, City of New York. Inspector of Medical Supplies, Baking Powder, etc., for the Indian Bureau of the Interior Department.

FERRER, CARLOS FERRER, C.E., ... 1883.
39 Broad Street, New York City.

After graduation for a few weeks on work at the School of Mines. Then under Mr. W. E. Worthen, C.E., on some work for the Water Commissioners of the State of New Jersey. From March 1, 1884, to January, 1887, on the Engineering Corps of the Aqueduct Commissioners, New York City, as Assistant to Engineer of Construction; Leveler in charge of field work on Section "A"; reduced to Rodman in charge of same; promoted to Assisant Engineer; resigned in January, 1887, and have since been engaged in business for my own account at above address.

FERRIS, JUNIUS COLTON, E.M., ... 1883.
Carthage, Ills.

FEUCHTWANGER, HENRY, PH.B., ... 1882.
Room 19, 99 Franklin Street, New York City.

FIALLOS, ENRIQUE CONSTANTINO, C.E., ... 1883.
No. 27, Calle 10a, Tegucigalpa, Honduras, C. A., and care Ernest Schernikow, P. O. Box 3540, New York City.

General Practice in Engineering. Professor of Mathematics and Mineralogy in the University of Tegucigalpa. The most extensive practice has been as Government Surveyor of Lands and Mines.

FISHER, HENRY, ... 1899.
Columbia Univ. and 108 East 70th Street, New York, N. Y.

Assistant in Analytical Chemistry.

FISHER, WILLARD, E.M., ... 1888.
Manager Sales Department Continental Watch Co., 366 Washington Street, and 361 W. Fifty-sixth Street, New York City.

Draughtsman to W. B. Parsons, C.E., New York City. Assistant to Superintendent Segovia Gold Mining Co., Nicaragua. Clerk, Office of Rich Hill Coal Mining Co., Rich Hill, Mo. Engineer and Mine Surveyor Rich Hill Coal Mining Co., Rich Hill, M. Prospecting for coal, Southwest Missouri, along the line of Wichlaw & Western in the interest of the Missouri Pacific Railroad. Southern Sales Agent, Coal Cos., on the lines of Missouri Pacific Railway. President Tyler S. E. Railway of Texas. 1897, Agent Illinois Zinc Co. 1898, Manager Sales Department Continental Match Co., and Eastern Sales Agent Illinois Zinc Co.

FLIESS, ROBERT A., E.E., ... 1899.
201 West 55th St., New York, N. Y.

With Met. R. R. in their Electrical Department.

FOERSTER, DAVID, E.M., ... 1895.
5 East Pearl Street, Cincinnati, O.

Chemist, N. J. Zinc and Iron Co. Assayer and Surveyor, West Creek, Colo.

FOLGER, EDWARD P., C.E., ... 1894.
80 Quincy Street, Brooklyn, N. Y.

FOSTER, PELL W. (Associate), ... 1883.
Power Specialty Company, 126 Liberty Street, and 158th Street and Hudson River, N. Y.

FOSTER, REGINALD GUY, C.E., ... 1893.
16 East 31st Street, New York City.

FOWLER, SAMUEL STEWART, A.B., E.M., . . . 1884.
Drawer 505, Nelson, British Columbia, and Room 201, 36 Clark Street, Chicago, Ill.

1885, Civil Engineering Work, New York. 1886, Assistant Superintendent, Iron Hill Mining and Milling Co, Black Hills, South Dakota. 1887, Assistant Superintendent Galena Reduction Co., Black Hills, South Dakota. 1888, Superintendent, International Smelting Works, Texas. Engineer and Assayer, Bunker Hill and Sullivan Mg. and Conc. Co., Idaho. 1889, Reporting sundry properties. 1890 to 1892, Superintendent Golden Mining and Smelting Co., Golden, B. C.,

Canada. Deputy Commissioner World's Columbian Exposition, 1893. 1894-95, Sundry Examinations in British Columbia. Engineer the London and British Columbia Goldfields, Whitewater Mines Ltd. and Ymir Gold Mines Ltd., Nelson, B. Col., 1896 to date.

FOYÉ, ANDREW ERNEST, C.E., ... 1890.
21 Park Row, and 11 Broadway; also 163 West 79th Street, New York City.

1890–92, Engineer's office, M. W. P. R. R. 1892-94, Tutor in Civil Engineering, School of Mines. 1894 to date, Instructor in the same. Contractors' Consulting Engineer Nyack Sewerage System, Chief Engineer Inter-State Contracting and Construction Co. Ch. Eng. Construction Sodi Water Co. Ch. Eng. Constructions, Macademizing roads, Borough of Sodi. July 1, 1898, Resigned Position of Instructor in Civil Engineering Columbia University, to give whole attention to private practice. August 15, 1893, Appointed Principal Assistant Engineer Dept. Highways New York City in charge of Riverside Drive, Viaduct and other Improvements. Jan., 1899, to date Acting Chief Engineer of same.

FRANK, JEROME WILLIAM, PH.B., ... 1888.
20 Broadway, New York City.

FREEDMAN, WILLIAM HORATIO, C.E., E.E., . . 1889.
Professor of Electrical Engineering, University of Vermont, Burlington, Vermont.

Post-graduate in Elect. Engineering, 1889–91. John Tyndall Fellow, 1891–92. Assistant to Professor Munroe in Surveying, Summers of 1890-92. Assistant to Professor Rees in Geodesy, Summer of 1891. Tutor in Electrical Engineering, School of Mines, 1892–95. Tutor in Mechanics, Columbia University, 1895 to 1898. Tutor in Electrical Engineering, Columbia University, 1898-99. Professor of Electrical Engineering University of Vermont, 1899 to date. Teacher and Lecturer in University Extension work, 1894–97. Public Lecturer to Board of Education for three terms in 1895–96 and one term in 1896–97. Associate Editor of Electric Power, 1895–96. Member of Firm, Freedman, Rennard & Co., Electrical Engineers and Contractors February, 1894, to February, 1898. Asst. Editor School of Mines Quarterly, 1897. Member of American Mathematical Society and Full Member of American Institute of Electrical Engineers.

FRIEDMAN, SAMUEL, C.E., ... 1892.
Tuscaloosa, Ala.

FULTON, CHARLES H., E.M., ... 1897.
Instructor University of Wyoming, Laramie, Wyoming and Bay 8thStreet, and Bath Avenue, Brooklyn, New York.

Assistant in Assaying, Columbia University, 1797-98, Assayer and Superintendent Hecla Cons. Gold Mining Co., Holy Cross, Colo., 1898-99. Instructor in Mining and Metallurgy, University of Wyoming 1899.

FURMAN, HOWARD VAN FLEET, E.M., . . . 1881.
Room 309 Boston Building, Denver, Col.

1882–88, Assayer and Chemist and Foreman, Germania Lead Works, Utah, Chemist, Globe Smelting and Refining Co., Denver. Assistant Superintendent, Billings Smelter, Socorro, New Mexico. Superintendent, Bailey Smelter, Den-

ver, Colo. 1888–94, Consulting Mining Engineer and Metallurgist, Office in Denver. 1894 and 1895, Chief Assayer U. S. Mint, Denver, Colo. 1896, Professor of Mining and Metallurgy, Colorado State School of Mines, Golden, Colo., also office as above. Feb., 1898, to Dec., 1899, travelling on professional business in Africa, Asia, Europe, Mexico and the United States. Consulting Mining Engineer and Metallurgist with office in Denver, as above.

G.

GARLICHS, HERMAN, E.M., ... 1880.

Supt. Guggenheim Smelting Company, Mauser, N. J.

1880–83, Surveying and Reporting on Mines in Colorado. 1883–87, Assistant Superintendent, Aurora S. & R. Co., Aurora, Ill. 1887–94, Superintendent Refining Department, Omaha and Grant S. and R. Co. Specialty, Silver and Lead Smelting and Refining. 1894, Metallurgist, Velardena Mining Co. Superintendent Refining Department. Cons. K. C. S. & R. Co. Oct. 1, 1895, to 1899, Superintendent Smelting and Refining Departments, 1897.

GIFFORD, STANLEY DEVOE, E.M., ... 1889.

Treasurer, Montana Ore Purchasing Co., 100 Broadway, New York, and Butte, Montana, also 57 West 75th Street, New York City.

Treas. Montana Ore Purchasing Co., of Butte, Montana, Vice-President British Columbia Smelting and Refining Co., of Trail, B. C., and Vice-President of The Columbia and Western Railway Co., of Trail, B. C.

GILDERSLEEVE, ALGER C., C.E., ... 1895.

28 West 48th Street, and 39 Cortlandt Street, New York City.

1889-92, Studied Law; 1892, Laborer; 1893, Transitman; 1894. Assistant Engineer, Department of Docks, New York City, resigned in June, 1894, to accept position as Engineer for John C Rogers, Contractor, on construction of the Second Section Harlem River Driveway. Resigned in November, 1895, and opened a private office at 39 Cortlandt St., as Engineer and Contractor for Piers, Docks, Foundations and Heavy Masonry.

GILLETTE, HALBERT POWERS, ... 1892.

Assistant State Engineer, Powers Block, Rochester, N. Y.

1892-94, Deputy County Surveyor on Highways and Bridges. 1894-95, Boat Railway Survey, Dallas, Ore., contractor and designer for highway bridges. 1894, Asst. Summer School of Surveying, School of Mines. Asst. Dept. Physics, 1895. Asst. to State Engineer, N. Y., on Canal Improvements. Assistant New York State Engineer since March 1, 1896.

GODLEY, RICHARD D., JR., E.E., ... 1896.

Department of Public Building, Lighting and Supplies, Jamaica, Borough of Queens and Whitestone Landing, Borough of Queens, N. Y.

October, 1896. joined the Brotherhood of Electrical Workers, Knights of Labor and did practical work as a journeyman wireman for one year with the different electrical equipment companies of New York City, chiefly with the Tucker Electrical Equipment Co., from October 1, 1897, to April 1, 1898. Superintenden-

New Jersey Electrical Equipment Co., from April 1, 1898, to the present, Consulting Engineer of Lighting and Electricity to the Department of Public Buildings, Lighting and Supplies, Borough of Queens, New York City.

GOING, CHARLES BUXTON, PH.B., ... 1882.
Editor Engineering Magazine, 120–122 Liberty Street, New York City.

1882, Chemist to the Cincinnati Desiccating Co. 1884, Porter & Going, Cincinnati, Ohio, expert and consulting practice. 1887–96, Vice-President, General Manager and President of the Cincinnati Desiccating Co., Cincinnati, Ohio. 1892–96, Trustee, Secretary and Treasurer of the Glendale Water Works, Glendale, Ohio.

GOLDSCHMIDT, SAMUEL ANTHONY, A.B., A.M., E.M., PH.D. (Life Member), ... 1871.
President Columbia Chemical Works, 43 Sedgwick Street, Brooklyn, N. Y., and New York City.

Assistant Ohio Geological Survey, 1871. Chemist and Assistant Inspector of Fertilizers, Savannah, Ga., during winters of 1871–75. During summers, Assistant to Dr. Chandler, 1871–73. Inspector New York Board of Health, 1873–75. Reporting on Guano Islands, South Pacific, 1876. General Consulting Practice, 1876–80. Inspector of Offensive Trades, New York Board of Health, 1879–88. Treasurer Columbia Chemical Works, 1890–91. President Columbia Chemical Works, 1891 to date.

GOOD, GEORGE MCCLELLAN HOUTZ, E.M., . . . 1886.
Osceola Mills, Clearfield Co., Pa.

1887–91, Engineer to the Houtz Estate, Houtzdale, Pa. 1892, Mining Engineer to the United Collieries Company. 1892, Assistant General Manager of the same. Also in 1895, Assistant Engineer Altoona & Phillipsburg connecting R. R. July, 1895, Chief Engineer of same. August, 1897, General Superintendent A. & P. C. R. R.

GOODELL, GEORGE ARTHUR (A.B., 1894, Amherst), A.M., 1898.
Asst. in Chemistry, Barnard College, Columbia University, 119th Street, and Bould. and 284 St. Nicholas Ave., New York City.

GOODWIN, EDWARD, E.M., ... 1891.
Moscow, Idaho.

July, 1887, to October, 1889, on Harlem River Canal, New York. 1891, Assistant in Mineralogy, and to spring of 1893, Assayer for Tombstone Mill and Mining Co., Tombstone, A. T. Spring of 1893, Experimental Cyanide Plant at Tombstone, A. T. Fall of 1893 to summer, 1894, Assayer at Texas Con. Gold Mine, and Assayer and Assistant Superintendent at Bully Choop Mines, Shasta Co., California. December, 1894 to June, 1895, Assayer, Puget Sound Red. Co., Everett, Wash. June, October, 1895, Assayer and foreman, Monto Cristo Mining Co., Monto Cristo, Wash. October, 1895, Prof. Mining, University of Idaho, Moscow, Idaho.

GORDON, JOHN, E.M., ... 1871.
Care of G. O. Gordon, 66–70 Beaver Street, New York City.
Merchant, Edward Johnson & Co., 62 Sas Pedro, Rio de Janeiro, Brazil.

GOSLING, EDGAR BONAPARTE, E.M., PH.D., . . 1884.
In Europe.

Tutor in Mathematics, Columbia University, from 1884 to 1885. Draughtsman and afterwards Assistant Engineer in Departments of Docks, New York City, 1886–88. In Manufacturing Business in Paris, France, 1888–89. Tutoring in Mathematics and Engineering Branches in New York, and Superintending building of houses, introducing Culm-burning Furnaces in U. S., 1889–91. In charge of erection of buildings in artificial stone (Beton Coignet), for the Suez Canal Company, Egypt.

GOULD, EDWIN H. (Associate) (Life Member), . . . 1888.
195 Broadway, New York City, and Ardsley-on-Hudson, N. Y.

GRAFF, CHARLES EVERETT, E.M., ... 1885.
Eagle Works, 26 Broadway, New York, N. Y., and 27 Clinton Ave., Jersey City, N. J.

1885–87, Assistant Engineer, Central Entre Riano Railroad, Argentine Republic, S. A. 1887–88, Engineer, Arizona Union Mining Co., Prescott, Arizona. 1888–90, Manufacturing Work, Binding Twine and Reapers. 1890–91, Engineer, Eagle Oil Co.

GRANGER, A. D., C.E., ... 1892.
Burnhorn & Granger, 95–97 Liberty Street, New York City, and 677 Greene Avenue, Brooklyn, N. Y.

Summer and Fall, 1892, with C. W. Hunt Co., and E. P. Gleason Mfg. Co., a draughtsman. November, 1892 to November, 1893, draughtsman, Link Belt Engineering Co., New York branch. Member of firm of Burhorn & Granger from November, 1893, to date. Specialties: Boilers, Engines, Complete Steam and Electric Plants.

GRATACAP, LOUIS POPE, PH.B., ... 1876.
Curator American Museum Natural History, Seventy-seventh Street and Eighth Avenue, New York City, and West New Brighton (Richmond County), Staten Island, N. Y.

GREENE, DAVID JOY, C.E., M.E. (Sibley College), . 1894.
300 Oakland Avenue., Brooklyn, N. Y.

June, 1895, graduated from Sibley College, Cornell University with degree of Mechanical Engineer. August, 1895–98, Superintendent of the Standard Silica Cement Co., Long Island City, N. Y. 1898, Superintendent Jordan Works, Am. Cement Co., Jordan, N. Y.

GREENLEAF, JAMES LEAL, C.E., ... 1880.
Consulting Engineer, No. 1 Broadway, New York City, and Somerville, N. J.

Special Agent for Tenth Census for Water-power from 1880–82. Since instructing in Engineering, civil and sanitary, in School of Mines, Columbia University. 1891, Adjunct Professor Civil Engineering, Columbia University. Resigned professorship in 1895 and gave exclusive attention to business as Consulting Engineer.

GROSS, LOUIS NATHAN, B.S., E.M., ... 1884.
Merchant and 38 East Fifty-eighth Street, New York City.

GUDEMAN, EDWARD, PH.B., PH.D., ... 1887.
The Glucose Sugar Refining Co., Chicago, Ill., and Box 3001, New York City.

Student at Berlin and Göttingen, 1887–89. Honorary Assistant at the S. of M. and Private Assistant to Professor C. F. Chandler, 1889–90. Professor of Chemistry, in charge of the Department of Chemistry, Dyeing and Pottery at the Pennsylvania Museum and School of Industrial Art, Philadelphia, Pa., 1890–91. Chemist with the American Glucose Co., at Buffalo, N. Y. and Peoria, Ill., 1891–92. Chemist and Superintendent of the Peoria Grape Sugar Co., 1892–95. Superintendent Davenport Syrup Refining Co., Davenport, Ia., 1895–97. Superintendent the Glucose Sugar Refining Co., Chicago, Ill., 1897 to date.

GUDEWILL, CHARLES EDWARD, C.E., . . . 1890.
Montreal Pipe Foundry Ltd., Canada Life Building and 18 St. Matthew Street, Montreal, Canada.

1890–91, Assistant in Engineering Department, School of Mines under Professor Trowbridge. 1891–96, Assistant Engineer Dominion Construction Co, Montreal, Canada. In charge of all pipe laying for Montreal Water and Power Co. Engineer of reservoir built by the company, capacity 7,000,000 gallons. Superintendent crossing of Lactine Canal with lines of 14-inch flexible pipes. January 1, 1897, appointed Engineer of Montreal Pipe Foundry Co., elected Vice-President April, 1897. Made Survey of Lac à la Fortue, Canada, for the Canada Iron Furnace Co., in June, 1897, and located ore deposits in lake. September 1, 1897, elected Associate Member American Society of Civil Engineers.

GUITERMAN, EDWARD WOLF, PH.B., ... 1889.
Passaic Print Works, and 125 Pauleron Ave., Passaic, N. J.

1890–1900, Chemist, Passaic Print Works, Passaic, N. J.

HAAS, EDWARD F., B.S., C.E., ... 1894.
320 Sansome Street, San Francisco, Cal.

1894–96, with City Engineers of Stockton, Cal. 1896–97, Assistant Engineer of Old River Land and Reclamation Co. 1898 to date, in private practice, also Assistant Engineer with Board of Engineers designing Sewer Systems for San Francisco.

HAASIS, DUNBAR FERDINAND, E.M., ... 1883.
U. S. S. "Gedney," and 59 Rector Street, Perth Amboy, N. J.

1883–84, Inspector of bridge work, Stony Point, N. Y. 1885–88, Assayer and Chemist, afterwards General Manager Parral Mining and Milling Co. (silver), Mexico, 1889, with Corps of Engineers, U. S. A., on New York Harbor Improvements. 1890 to date, Engineer Marion Phosphate Co., Florida, and Engineer Hamburg Phosphate Co., Florida, surveying, prospecting and reporting on phosphate deposits. 1892–93, with U. S. Engineers in charge construction Concrete Fortifications. In charge of Harbor Improvements. Assistant Engineer Dominion Construction Company for pipe laying and Reservoir engineering.

HADDEN, HOWARD S., B.S., PH.B., ... 1895.
106–108 Beekman Street, New York City, and 136 Willow Street, Brooklyn, N. Y.

HAFFEN, LOUIS FRANCIS, A.M., C.E., . . . 1879.

President of the Borough of Bronx, New York City, Municipal Bldg., 177th St. and 3d Ave., Borough of Bronx, and 647 Cortland Avenue, 23d Ward, New York City.

Engineer Department of Parks, N. Y. City, 1883-90. Superintendent and Engineer in charge of New Parks, 1890-93. Commissioner of Street Improvements, 23d and 24th Wards, 1893-98. President of the Borough of the Bronx, since January 1, 1898.

HALL, ROBERT WILLIAM., E.M. . . . . 1876.

Chemical Building, University of New York, University Heights, 24th Ward, New York City.

From 1879 to 1888, Chemist to the American Gas, Fuel and Light Company and to some associated companies. Since the autumn of 1888, Acting Assistant Professor of General Chemistry in the University of the City of New York. Since the autumn of 1890, also Acting Professor of Analytical Chemistry in the same institution. 1891, Professor of Analytical Chemistry, same institution.

HALLOCK, ALBERT PETER, PH.B., PH.D., . . . 1880.

440 First Avenue, New York City, and 161 Sidney Avenue, Mt. Vernon, N. Y.

June, 1880, to October, 1880, with Dr. de P. Ricketts. October, 1880, to November, 1887, Chemist Consolidated Gas Co. November, 1887, to January, 1889, in the shell lime business. January, 1889, to date, Chemist to Carl H. Shultz, Mineral Water Factory. Specialty, Gas and Mineral Water Chemistry.

HAMILTON, FRANK C., E.M., A.M., ... 1894.

General Manager The Gold Creek Nevada Mining Company, Gold Creek, Nevada.

1894, Assistant Assayer Colorado Smelting Co., Pueblo, Colorado. 1895-98, Assayer Brodie Gold Red. Co., Cripple Creek, Colorado. 1898 to date, General Manager of The Gold Creek Mining Co., Gold Creek, Nevada.

HANKINSON, ALBERT WORTHINGTON, C.E., . . . 1893.

114 West Forty-fifth Street, New York City.

HANNA, GEORGE BYRON, A.B., E.M., . . . 1868.

Assistant Assayer United States Assay Office, Box 56, Charlotte, North Carolina.

Chemist and Assistant Geologist, North Carolina Geological Survey. Melter and Assistant Assayer U. S. Assay Office, Charlotte, N. C. Also, Consulting Mining Engineer and Chemist, etc.

HANSON, RICHARD COCHRAN, C.E., ... 1894.

96 Park Place and 74 West 91st Street, New York City.

HARDING, GEORGE EDWARD (Associate), . . . 1867.

Architect and Civil Engineer, 253 Broadway, New York City, and Mayhurst, New Brighton, Staten Island, N. Y.

Fellow American Institute Architects and Member American Society Civil Engineers.

HARRINGTON, THOMAS HENRY, C.E., ... 1889.

Westchester, Westchester County, N. Y.

July, 1888, to March, 1893, Inspector Clerk and General Superintendent on U. S. Works, Flood Rock, Hell Gate, East River, N. Y. April to November, 1893, in charge of Exhibit of River and Harbor Improvements from New York City and Hudson River, at World's Columbian Exposition, Chicago. 1894-98, Assistant in Department Mechanical Engineering School of Mines, Columbia University.

HARRIS, EDWIN A., PH.B., ... 1889.

1294 Columbus Avenue, New York City.

1889-90, Chemist of the Camden Consolidated Oil Company. 1890 to date, Chemist Camden Consolidated Oil Company and agent for oil, mineral and timber lands in West Virginia and Ohio. Chemist to the Phosphorus Works of J. J. Allen's Sons, 2 Chestnut street, Philadelphia, 1892-93. April, 1893 to 1898 Secretary and Treasurer Globe Steam Heating Company.

HARTE, CHARLES R., C.E. . . . . 1893.

Room 461, South Station, Boston, Mass., and 286 Chestnut Avenue, Jamaica Plain, Boston, Mass.

Engineering Department, N. Y., N. H. & H. R. R. on four-track elimination of grade crossings at Milfred, Conn., 1893-94, and at Boston, Mass., 1894 to date.

HASKELL, G. M., E.E., ... 1898.

229 West 28th Street, New York City, and 27 Morris Place, Bloomfield, N. J.

HASKELL, HARRY GARNER, E.M., ... 1893.

Secretary Repauno Chemical Co., and Hercules Powder Co., Wilmington, Del.

HATHAWAY, NATHANIEL, PH.B., ... 1879.

Swain Free School, and 43 Elm Street, New Bedford, Mass.

1879-80, Booth and Edgar Sugar Refinery. 1880-83, Private Assistant to Dr. E. Waller, New York. 1883-91, Teacher of Chemistry and Physics, Swain Free School, New Bedford, Mass., and general analytical work.

HAWLEY, JOHN FRANCIS, E.E. (Life Member), . . 1891.

Finca "El Tambor," San Filipe, Guatemala, Central America.

HÉRBERT, OCTAVE BRITTON, C.E., ... 1888.

70 and 72 Broad Street and 72 West 69th Street, New York City,

HEINSHEIMER, ALFRED MAURICE, C.E., . . . 1887.

133 West 42 Street, and 17 West 70th Street, New York City.

October, 1897, entered firm of Traidel Bros. & Co., tile, marble and mosaic work, mantels, etc.

HENDRICKS, HENRY HARMON, P.B. (Life Member), . 1880.

Hendricks Bros., 49 Cliff Street, New York City.

HERZIG, C. S., E.M., ... 1895.

Supt. Stone Hill Copper Co., Stone Hill, Cleburne Co., Ala., and 33-35 West Houston Street, New York City.

1895–96, Anaconda Copper Mining Co., Anaconda and Butte, Montana. 1896-97. Boston and Montana C. C. & S. Mining Co., Great Falls and Little Rock Mountains, Montana. 1897, professional work in Montana, South America, South Carolina and New York. December, 1897, to date, with La Gran Fundicion Nacional, Mexicana.

HEWLETT, JAMES MONROE, PH.B., ... 1890.

Lord & Hewlett, Architects, 16 East Twenty-third Street, New York City, and 154 Hicks Street, Brooklyn, N. Y.

Member Am. Inst. of Architects and Architectural League of New York.

HILDBURGH, WALTER LEO, E.E., A.M., . . . 1897

Care D. H. Hildburgh, Hotel Vendome, New York, N. Y.

1898, Post-Graduate Study School of Applied Science, taking degree of A.M.

HILDRETH, WALTER EDWARDS, C.E., E.M., . . 1877.

Room 76, 115 Broadway, New York City.

HILL, WILLIAM, C.E., ... 1882.

Agent Collins Company, Box 196, Collinsville, Conn.

One year practical experience in manufacture of crucible steel. Two years draughtsman and Assistant to Master Mechanic of company manufacturing crucible steel, bar-iron, edge tools, plows and wrenches. Engineer in charge of Reconstruction of a dam 600 feet long, 32 feet high, at Otis, Mass. 1886-91, Assistant Superintendent for the Collins Company, manufacturing principally edge tools. November 1, 1891, appointed Agent of the Collins Company, with genera charge of plant at Collinsville, Conn., employing about 650 men, which position he still holds.

HINMAN, BERTRAND CHASE, PH.B., A.M. (1892), . 1890.

9–11 Worship Street, London, E. C., England.

From June, 1890, to August, 1891, Chemist to the Iron Clad Manufacturing Co., of Brooklyn, N. Y., improving the manufacture of sheet-iron enamelled ware. August, 1891, to June, 1895, Consulting Chemist for same company. August, 1891, to March, 1893, Private Assistant to Professor Waller at the School of Mines. March, 1893, to end of the year, Manager of the Amorphous White Lead Co., of Brooklyn, N. Y., also a Director and subsequently President of this company. 1894, was devoted to experimental research on the improvement of methods for treating refractory gold ores. June, 1895, to end of 1896, Manager and Director of the "Nellie Bly Gold Mining and Reduction Co.," of Boulder, Colo., engaged in exploiting the "Cassel-Hinman Bromine process" for refractory gold ores. Since 1896, Manager of the "Gold Extraction and Bromine Recovery Co., Ltd.," of London, England, exploiting the Cassel-Hinman Process.

HOLBROOK, FRANCIS NEWBERRY, C.E., . . . 1876.

Box 395, Tarrytown, N. Y.

From Fall, 1876, to spring, 1880, Assistant Assay Laboratory, School of Mines. Spring and summer on Geological Survey, West Texas. Then to 1884, spring, Superintendent Corralitos Co., Chihuahua, Mexico. 1884–87, expert work, office, El Paso, Texas. Summer and fall, 1887, Superintendent of United Verde Copper Company, Arizona. 1888, spring, on geological work for the Southern Pacific Company in West Texas. Summer and Fall, running gold mine and Mill

for self in Arizona. 1889–90, Manager for U. S. Circuit Court in suit between the Con. Kansas City Smelting and Refining Company and the Guadalupe Company, in Nueva Leon, Mexico. 1890 to February, 1891, employed by the Compañia Métalurgica Mexicana. March and April, 1891, charge of Copper Smelter, Tucson, Arizona. Expert work until 1892, when returned to Comp. Metal, Mexico. Still employed by the Compañia Métalurgica Mexicana and the Mexican Northern Railway Co.

HOLDEN, EDWIN C., B.S., E.M., ... 1896.

Box 505 Nelson, British Columbia, and 162 West 136th Street, New York City.

1896, Assistant Summer School of Surveying; Assistant in Mining Department 1896-97. 1897, Assistant in Analytical Chemistry, Columbia University. December, 1897, to date, Assistant Engineer, London and British Columbia Goldfields, Ltd.

HOLDEN, EDWARD HENRY, C. E., ... 1878.

1074 Boston Avenue, New York City.

HOLLICK, ARTHUR, PH.B., PH.D., ... 1879.

Geological Department, Columbia University, New York City, and New Brighton, N. Y.

Superintendent Mexican Mine, Mariposa, Cal., 1880. New York City Health Department Inspector from 1881–90. Sanitary Engineer from 1890 to 91. Special Inspector, 1892. Special Expert and Inspector of Offensive Trades, New York State Board of Health, both in consultation and field work, from 1883 to date. Board of Health, Village of New Brighton, 1886-92, a member of the Board. Board of Health, Long Island City, Sanitary Adviser, 1890. In general practice as a sanitarian from 1883 to date. U. S. Geological Survey—engaged in collecting specimens in the Territories, in 1882. Appointed Fellow in Geology, Columbia College, January, 1890; reappointed, 1891; Assistant, 1892. 1893, Tutor in Geology. Recording Secretary, Torrey Botanical Club, N. Y.; 1883–88. Secretary, Natural Science Association of Staten Island, 1881 to date. Associate Editor *Bulletin*, Torrey Botanical Club, 1888 to date. Librarian New York Academy of Sciences, 1894 to 1899. Treasurer, Botanical Society of America, 1896 to date. Commissioner and President, Port Richmond (Staten Island) Boulevard Commission, 1896. Commissioner and Vice-President, Richmond County (Staten Island) Park Commission, 1897. Secretary, Section E, American Association for the Advancement of Science, 1898–99.

HOLLIS, HENRY LEONARD, E.M., ... 1885.

Mining and Metallurgical Engineer, 1161 The Rookery, Chicago, Ill.

HOLLIS, WILLIAM, C.E., ... 1878.

Box 133 Eagle Pass, Texas, Great Sales Agent for Alamo, Fuente and Coahuila Coal Companies.

HOLT, MARMADUKE BURRELL, E.M., ... 1889.

Silverton, Colo., and 287 Lexington Avenue, New York City.

1889–90, Student in course of Electrical Engineering, School of Mines. 1890–91, with Aspen Mining and Smelting Company, serving as Mining and Electrical

Engineer. 1891 to fall of 1892, Agent and Electrical Engineer with the "C. and C." Electric Motor Co., New York City and Denver. 1892-93, Assayer Colorado Smelting Co., Pueblo, Colo.

HOOPER, FRANK CYRUS, MET.ENG., ... 1890.

North River Garnet Co., North River, Warren Co., N. Y.

1890-91, Assistant Engineer De Lemar Mining Co., Limited. 1892-93, American Graphite Co. Spring, 1893, Investigation and report on Sisal Hemp Industry in The Bahamas for The Inauga Fibre Co. Summer and Fall, Erection of Concentrating Plants in Adirondacks. Superintendent North River Garnet Co., from 1893 to date. 1897-98, Assistant in Mining, School of Mines.

HOPKE, THEODORE M., PH.B., ... 1880.

Monongahela Furnace Dept., National Tube Co., and 1107 South Park Street, McKeesport, Pa.

August, 1880 to November, 1881, Analytical Chemist with Ledoux & Co., New York. November, 1881, to November, 1885, Member of the firm of Elliott Hopke & Mattison, Analytical and Consulting Chemists and Assayers. July, 1886, to November, 1889, Chemist for London Steel Co., of Pittsburg, Pa., also had charge of physical testing department. November, 1889-94, Manager Open-Hearth department of above company, having full charge of manufacture of all grades of steel made by the Company, also building of open-hearth furnaces. 1894, Secretary and Assistant to General Manager, McKeesport Supply Company. 1897, Superintendent O. H. Dep't, Apollo Iron and Steel Co., Apollo, Pa. 1898, Monongahela Furnace Co., McKeesport, Pa. 1899, Superintendent 35" Blooming Mill.

HORNE, WILLIAM DODGE, PH.B., PH.D. (1894), . 1886.

Yonkers, N. Y.

June, 1886, to December, 1887, Chemist to Fulton Sugar Refinery, Brooklyn, N. Y. October, 1887, to December, 1887, Assistant Instructor in Chemistry, School of Mines, Columbia University. December, 1887, to June, 1888, Chemist to St. Louis Sugar Refinery, St. Louis, Mo. October, 1888, to October, 1889, Chemist to Standard Sugar Refinery, Boston, Mass. November, 1889, to present time, General Analytical and Consulting Chemist. January, 1890, to January, 1893, Consulting Chemist to Delaware Sugar House, Philadelphia. January to June, 1891, Instructor in Analytical Chemistry in Rutgers College, New Brunswick, N. J. May, 1893, to present time, Consulting Chemist to National Sugar Refining Co., Yonkers, N. Y. Laboratory and office in New Brunswick from November, 1889, to September, 1893. From September, 1893, to present time in Yonkers, New York. In June, 1894, received from Columbia College the degree of Ph.D. in the Department of Chemistry and of Mechanical Engineering.

HOWE, EPENETUS, E.M. (Life Member), . . . 1886.

Box 68 Monterey, Mexico, and North Salem, Westchester County, N. Y.

Assayer and Chemist with the El Paso Smelting Co., and the Argentine Works. Kansas, 1887-89, and with Lucia Constancia Esmeralda Sierra Mojada Coahuila, Mexico, 1889. Assayer, Chemist and then Superintendent, 1888 to 1895. May, 1895, to date, engaged in irrigation, mining and other engineering work for self on contract. 1897 General Assay and Mining Business and Consulting Engi-

neer. Since summer of 1897 Engineering and Assay office of How & Norton, Monterey, Mexico.

HUNT, FREDERICK FURNEAUX, E.M., C.E., . . 1876.
77 Pine Street, New York City, and 41 St. Marks Place, New Brighton, S. I., N. Y.

HUNTOON, L. D., E.M., PH.G., ... 1895.
Care of Ricketts & Banks, 104 John Street, New York City, and Paterson, N. J.

1895, Assistant Chemist, Philadelphia Smelting and Refining Company, Pueblo, Colo. 1896, Assayer American Reduction Company (Cyanide Mill), Florence, Colo. 1897, with Ricketts & Banks, New York City, making metallurgical tests and Superintendent of Diamond Drill operations at Ducktown, Tenn. 1898, Superintendent of Mines, Ducktown Sulphur Copper and Iron Co., Ducktown, Tenn. 1899, Reporting on mineral properties for Ricketts & Banks, New York City.

HUTTON, FREDERICK REMSEN, A.B., A.M., E.M., C.E., PH.D. (Life Member), ... 1876.
Professor of Mechanical Engineering, Columbia University, and 319 West 107th Street, New York City.

1876–77, Assistant in Engineering, School of Mines. 1877–82, Instructor in Mechanical Engineering. 1882-91, Adjunct Professor Mechanical Engineering. 1891 to date, Professor Mechanical Engineering, Columbia University. Secretary Alumni Association School of Mines, 1883 to date. Secretary American Society Mechanical Engineers, 1882 to date.

HYDE, FREDERICK S., PH.B., ... 1896.
215 Schermerhorn Street, Brooklyn, N. Y.

1893–94, Investigations in Glass for L. C. Tiffany, New York City. Assistant Chemist Brooklyn Department of Health, May, 1894–98. 1898–99, Assistant in Analytical Chemistry, Columbia University. 1899 to date, Chemist Joseph Dixon Crucible Co., Jersey City, N. J.

HYDE, HENRY ST. JOHN, PH.B., A.M. (1898), . . 1893.
210 East Eighteenth Street, New York City.

1897–98, Post Graduate Student, Columbia University ; Candidate for A.M. in School of Pure Science. 1898 to date, Candidate for Ph. D. in School of Pure Science Columbia University,

I.

IHLSENG, AXEL OLAF, B.S., E.M., C.E., . . . 1877.
Carthage, Mo.

1877–82, Chief Chemist, Havemeyer Sugar Refining Co., Brooklyn, E. D. 1882–90, U. S. Dep. Mining Surveyor, District of Colorado. 1882-83, Chemist and Assayer, La Plata Smelter, Leadville, Colo. 1883, Metallurgist, Martha Rose Smelter, Silverton, Colo. 1884, Assayer, Stoiber Sampling Works, Silverton, Colo. 1885, Duyckinck, Schuyler & Ihlseng, Ore Samplers, Silverton, Colo. 1886–90, Manager of Mt. Queen Mining Co., Reliance Mining Co., Brown Mining Co., and the Hale Mines, Silverton, Colo. 1890–92, Operating Zincite Mine and

others near Webb City, Mo., and in constructing concentrating plants. Manager Pleasant Valley Mines, Carthage, Mo. Zinc ore exporter.

ILES, MALVERN WELLS, PH.B., PH.D. (Life Member), . 1875.
Superintendent Globe Smelting Co., Denver, Colo.

1875-76, Assistant to Dr. Waller in the Qualitative Laboratory, School of Mines. 1876-78, Chemical Fellow, Johns Hopkins University. 1878-79, Assayer and Chemist, in Colorado. 1879-80, Assayer at the Smelting Works of J. B. Grant, Leadville, Colo. 1880-83, Chemist of the Grant Smelting Co., Leadville, Colo 1883-86, Metallurgist, the Omaha & Grant, S. & R. Co., Denver, Colo. 1886-87, Metallurgist, The Holden Smelting Co., afterwards changed to the Globe S. & R. Co. 1887-95, in present position. Contributed articles upon Assaying, various new Chemical methods, Mineralogy and Metallurgy in various publications.

INGERSOLL, WILLIAM HALSEY, A.B., A.M., LL.B., E.M.
(Life Member), ... 1870.
Northport, N. Y.

1875-78, Assistant in Engineering, Columbia University. 1978-81, Assistant in Mechanics and Astronomy. 1881-87, Manufacturing tinware, Portland, Conn. 1887, to date, retired on account of ill health.

INGRAM, EDWARD LOVERING, C.E., ... 1885.
Nyack, N. Y.

1885-86, U. S. Inspector of River and Harbor Improvements, Delaware. 1887-89, U. S. Surveyor and Inspector, River and Harbor Improvements, New York and New Jersey. 1890-91, U. S. Assistant Engineer River and Harbor Improvements, Florida. 1891-94, Principal Assistant Engineer, International Boundary Survey, United States and Mexico.. 1895 to date, Consulting Engineer.

J.

JACKSON, OSWALD, C.E., ... 1892.
21 Park Row, and 550 Park Avenue, New York City.

1892-93, Office of Engineer M. W., U. R. R. R.'s of N. J. Div., P. R. R., 1893, Engineer on Corps of Principal Assistant Engineer, U. R. R.'s of N. J. Div., P. R. R. 1895, Assistant Engineer, New York Steam Co. 1896 to date, Engineer Inspector Department Public Works, Department of Highways, New York City.

JACOBS, DAVID MARK, PH.B., ... 1887.
R. J. Jacobs, 41 New Street, and 30 West Thirty-eighth Street, New York City.

JACOBS, SOLOMON JOSEPH, PH.B., ... 1887.
R J. Jacobs, 41 New Street, and 30 West Thirty-eighth Street, New York City.

JANEWAY, JOHN HOWELL, E.M., ... 1886.
John A. Roebling's Sons Co., and 124 West State Street, Trenton, N. J.

1886, Underground and Surface Surveyor for Cooper, Hewitt & Co. 1887-91, Draughtsman and Designer and Constructing Engineer of Wire Rope Tramways in Montana, Oregon, Alaska and California for the Trenton Iron Co., Trenton, N.J.

JENKS, ARTHUR WILTON, E.M., ... 1886.
Superintendent Establecimiento Mineral, Casapalca, Peru, South America.

Summer, 1886, New Jersey on Geological Work. 1886-87, in Cerra de Pasco, Peru, S. A. Assayer and Chemist to the commission examining that silver mining district. Spring, 1887, in New York, Chemist with Ledoux and Co. 1887-88, in Aurora, Ill., Assistant at the works of the Chicago and Aurora Smelting and Refining Co. Summer and Fall, 1888, in Dutch Guiana, S. A., Assayer and Assistant in the examination of gold deposits. Fall, 1888-93, in Aurora Ill., Assistant Superintendent at the Aurora works of the Chicago and Aurora Smelting and Refining Co. 1883, Superintendent Kootenay Reduction Co. 1894, Superintendent Balbach Smelting and Refining Co., Newark, N. J.

JOBBINS, F. H., PH.B., ... 1895.
284 Pearl Street, P. O. Box 2195, New York City.

1895-98, Jobbins & Ruymelke, Analytical Experts and Mfg. Chemists, Aurora, Ill. 1898, Treasurer and Secretary Alba Chemical Co., New York City.

JOHNSON, ARTHUR GALE, E.M., ... 1885.
Jensen, Utah.

JOHNSON, ELIAS MATTISON, PH.B., ... 1878.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, GILBERT HENRY, PH.B., ... 1878.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, ISAAC BRADLEY, E.M., ... 1879.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSTONE, WM. B., C.E., ... 1895.
47 Central Avenue, New Brighton, S. I., N. Y.

JONES, J. ELMER, E.M., ... 1893.
Assistant Superintendent Mill Creek Coal Co., New Boston, Pa., and Hazelton, Pa.

JOPLING, REGINALD FURNESS, E.M., ... 1889.
Jopling & Escobar, Engineers, Room 508 Cuyahoga Building, Cleveland, O.

November, 1889, to February, 1890, Chemist, Otis Steel Co., Ltd. February, 1890-92, Assistant Manager American Wire Co. Vice-President of same, January, 1892.

JOSEPH, THEO. H., E.E, ... 1898.
32 East 74th Street, New York, N. Y.

JOÜET, CAVALIER HARGRAVE, PH.B., PH.D., . . 1882.
Roselle, N. J.

Analytical Chemist with Ledoux & Ricketts, 1882-85. Analytical Chemist with G. H. Nichols & Co., Acid Manufacturers at Laurel Hill, L. I., from 1885-88. Work comprising analyses of their various products and a partial supervision of their manufacture. Analytical Chemist from 1888 to 1896 with Ricketts &

Banks. Analyst with Guggenheim Smelting Co., from March, 1896, to March, 1897. 1897-99, Instructor in Analytical Chemistry at Newark Technical School and Assistant in Analytical Chemistry, Columbia University, 1899-1900.

K.

KASTNER, J. C., PH.B., ... 1894.
1133 Broadway, New York City, and Oyster Bay, L. I., N. Y.
Member of firm of Julius Kastner & Sons, 1898.

KEMP, JAMES FURMAN, A.B., E. M., ... 1884.
Professor Geology, Columbia University, School of Mines, and 211 West 139th Street, New York City.
Several months with the Rand Drill Co., 1883-84. Private Assistant to Professor J. S. Newberry, 1884-85. Student of Geology and Mineralogy at the University of Leipzig and Munich, Germany, 1885-86. Instructor in Geology at Cornell, 1886-88. Assistant Professor of Geology and Mineralogy, 1888-91, and Secretary of the Faculty, 1888-89. Have traveled much in the West, and for five summers past have been working on the Geology of the Adirondacks, chiefly as Assistant to the State Geologist, Professor James Hall. Am specially engaged on Inorganic and Economic Geology. 1891, Adjunct Professor of Geology, School of Mines, Columbia University. Professor, 1892. Secretary New York Academy of Sciences, 1893-98. Vice-President 1898-1900. Vice-President of the American Association for the Advancement of Science, and Chairman of the Section of Geology and Geography, 1899-1900. Manager Am. Inst. Mining Engineers, 1896-99. Editor *School of Mines Quarterly*, 1895-97, Engaged on the Geology of the eastern Adirondacks for the U. S. Geological Survey, since 1896, and for the N. Y. State Geological Survey since 1891.

KINSEY, FRANK WILMARTH, C.E., ... 1891.
Morris & Cummings Dredging Co., 22 State Street, New York City, and 58 Mt. Pleasant Avenue, Newark, N. J.
Assistant to Engineers, Rapid Transit Commission, 1891-92. Engineer of Construction East Providence Water Works, 1892. Designing Engineer with S. M. Gray, 1892-93. 1893, Manager for R. W. Hildreth & Co. 1895, Assistant Superintendent Morris & Cummings Dredging Co.

KIPP, BURDETT, C.E., ... 1898.
20 West 121st Street, New York City.

KIRBY, G. T., E.E., LL.B., ... 1895.
Attorney and Patent Lawyer, 2 Wall Street and 60 West 45th Street, New York City.

KISSAM, H. S., PH.B., ... 1886.
Bureau of Architecture, Pan-American Exposition, Buffalo, N. Y.

KLEPETKO, FRANK, E.M., ... 1880.
Butte and Great Falls, Mont.
Superintendent Smelting Department Tamarack, Osceola Copper Manufacturing Company, Dollar Bay, Mich. 1896, Superintendent of Construction of the Great Falls Smelter, for the Boston and Montana Consolidated Copper and Silver

Mining Company, Great Falls, Montana. 897, General Manager Mines and Smelters of Boston & Montana Con. C. & S. Mg. Co., and Butte & Boston Con. Mg. Co.

KNOX, NEWTON B., A.B., E.M., ... 1897.
Bodie, Cal.
Supt. Standard Cons. Gold Mining Co.

KOEN, JOSEPH JOHN, C.E., ... 1888.
Lynbrook, L. I., N. Y.
1883-89, Leveler and Topographer on New York City Croton Water Shed. 1890, to date, Sanitary Engineer on New York City Board of Health.

KUNHARDT, WHEATON BRADISH, E.M. (Life Member), 1880.
1 Broadway, and 763 Fifth Avenue, New York City, N. Y.
1880-82, Travel and Study in the West and abroad. 1883-88, Engineer Bower-Barff Rustless Iron Co. and Assistant to George W. Maynard in consulting work, Ore-dressing. 1888-89, First Assistant Engineer Boston Heating Co. 1890-91, Diamond Drill Exploration of Coal Deposits in Rhode Island. Reports on Direct Steel Processes, Magnetic Separation Iron-ores and on Croton Magnetic Iron Mines. Acting Secretary of the American Institute of Mining Engineers for four months. 1893, President Osceola Placer Mining Co. 1895, Vice-President Carpenter Steel Co., 1 Broadway, New York City.

KURTZ, EDWARD LAURENCE, E. M., ... 1893.
Care Indiana Elect. Ry. Co., Elkhart, Ind., and 17 Pittsburgh Street, New Castle, Pa.

L.

LACOMBE, CHARLES FREDERICK, E.M., . . . 1885.
The Mountain Electric Co., P. O. Box 1545, and 532-536 Seventeenth Street, and 1811 Grant Avenue, Denver, Colo. Also, University Club, New York City.
1885-86, Assayer and Surveyor and Foreman of Lucky Boy and South Galena, Mines, in Bingham, Utah. 1886-88, Assistant Instructor in Assaying, and Fellow in Chemistry, School of Mines, Columbia University, N. Y. 1888-90, Examining Gold and Silver Mines in Colorado, Utah, Montana, Arizona and Old Mexico. 1890, Testing Electrical Apparatus in Virginia City, Nevada. 1890, Manager of the Gilpin Co. Light, Heat and Power Co., Central City, Colo. 1890, to date, President and Manager, The Mountain Electric Co. Specialty, Installing Electric Light and Power Stations, and adapting electric light and power for mining purposes.

LADEW, J. HARVEY (Associate) (Life Member), . . 1885.
159 East Houston Street, and 813 Madison Avenue, New York City.

LAHEY, JOSEPH, E.M., ... 1887.
162 E. 86th Street, New York City.

LAHEY, RICHARD, E.M., ... 1887.
Millard & Lahey, 1429 Chestnut Street, Philadelphia, Pa.

LAMB, ANDREW JOHNSON, E.M., ... 1884.

L. & N. R. R. Co., Gallatin, Tenn.

June, 1884, to June, 1887, New York Croton Aqueduct, Draughtsman. June, 1887, to September, 1889, Assistant Engineer, L. & N. R. R. September, 1890, to June, 1891, Assistant Roadmaster, Knoxville Division, L. & N. R. R. June, 1891, to April, 1895, Assistant Engineer, L. & N. R. R. April, 1895, to date, Roadmaster, Main Stem, Second Division, L. & N. R. R.

LANGTHORN, JACOB S. (Associate), ... 1891.

Brooklyn Bridge Office, Washington Street, Brooklyn, and 79th Street between 3d and 4th Avenues, Bay Ridge, Brooklyn, N. Y.

1891, Surveying Land and R. R. Middlesborough, Ky., and Surveyor, Hondo Coal Co., Hondo, Coahuila, Mex. 1892, Draughtsman, Rapid Transit Comm., New York City, Craneman in Bessemer Mill, Carnegie Steel Co., Homestead, Pa. April, 1893, to October, 1893, Transitman R. R. Surveys on Long Island. October, 1893, to May, 1895, Elec. Insp., Foreman, Storekeeper, and Assistant Engineer, Brooklyn, Queens County, and S. R. R. Co. May, 1895, to Dec., 1895, Draughtsman, Rapid Transit Comm., New York City. Dec., 1895, to Jan., 1898, Assistant in charge of Docks and Bridges, Department of City Works, Brooklyn. June, 1898, to Sept., 1898, Boatswain's Mate, U. S. S. Elfrida. Jan., 1898, to date, Assistant Engineer, Department of Bridges, Borough of Brooklyn, New York City.

LAWRENCE, BENJAMIM BOWDEN, E.M., ... 1878.

Consulting Engineer, 404 Boston Building, and 1337 Gilpin Street, Denver, Colo.

1878–84, Superintendent Montezuma S. M. Co. and other mines of Summit County, Colo. 1884–89, Special work in Colo. 1889–97, Manager Dives-Pelican Mines, Georgetown, Colo., and Consulting Engineer, Denver, Colo.

LEARY, DANIEL JAMES, C.E., E.M., ... 1881.

43 East Twenty-fifth Street, New York City.

1882 to date, Constructing Highway and Railway Bridges, Wharves, Docks, Dredging and Harbor Improvements generally, in vicinity of New York City, as Designing and Supervising Engineer, as well as Contractor in most instances. In general, make a specialty of both Engineering and Constructing work, or Engineering work alone, in this branch of the profession.

LEARY, GEORGE, C.E., ... 1891.

43 East Twenty-fifth Street, New York City.

LEBOUTILLIER, CLEMENT, PH.B., ... 1881.

High Bridge, N. J.

1884–87, Assistant Chemist, Cambria Iron Co. 1887–92, Chemist Eliza Furnace. March, 1892, to date, Chemist, Taylor Iron and Steel Company.

LEDERLE, ERNST JOSEPH, PH.B., ... 1886.

Chief Chemist, New York City Health Department, Criminal Court Building, Centre and Franklin Streets, and 471 W. 143d Street, New York City.

1886–87, Hon. Fellow Quant. Anal. and Assist. Instr. Gen. Chemistry, School of Mines. 1887–88, Chemist, Cranmoor Farm, Tom's River, N. J. 1888–89, As-

sistant Chemist, New York City Health Dept. 1890-91, Chemist and Supt., Reed & Carnick, New York. 1891 to March, 1896, Assist. Chemist, New York City Health Dept. March, 1896, to date, Chief Chemist, also consulting Chemist to Health Officer, Port of New York.

LEDOUX, ALBERT REID, M.S., PH.D. (Associate), . 1874.
99 John Street, and 39 W. 50th Street, New York City.

LEE, GEORGE BARSTOW, E.M., ... 1885.
Superintendent Arkansas Smelting Co., Leadville, Colo.

1885, Assayer, Butte, Montana. 1886-87, Assayer, Kansas City Smelting and Refining Co., Argentine, Kan. 1887-90, Assistant Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1890-93, Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1894, Superintendent, Guggenheim Smelting Co. 1896, Superintendent, Union Smelting Co., Leadville, Colo. 1897 to date, Superintendent, Arkansas Valley Smelting Co., Leadville, Colo.

LEGGETT, THOMAS HAIGHT, E.M., ... 1879.
38 Mansion House Chambers, Cape Town, Cape Colony, and P. O. Box 485, Johannesburg, S. A. Rep.

1880, Assistant Engineer New York River and Harbor Surveys. 1881-83, Superintendent of Mining Properties in the Batopilas District, Chihuahua, Mexico. 1884, Travelling in the West, through the principal Mining Camps, Butte, Leadville, etc. 1884-87, Mining Engineer to the New York and Honduras Rosario Mining Co., at San Juancito, Honduras. 1888, Manager of Mudsill Mining Co., Fairplay, Colo.; office, 23 Bucklersbury, London, E. C. 1889-90, General Manager, Darien Gold Mining Co., Ltd., of Cana, Rep. of Colombia. 1891-95, President and Manager, Standard Consolidated Mining Co. Consulting Engineer S. Neuman & Co., of London and Johannesburg since July, 1895.

LENOX, LIONEL REMOND, PH.B., ... 1888.
Professor of Analytical Chemistry, Leland Stanford, Jr., University, Palo Alto, California.

LE PRINCE, JOSEPH A., ... 1898.
Mountain State Cons. Co., West Va., Short Line Ry. Engineer Corps, No. 2, Porter Falls, Wetzeh Co., W. Va.

LEVINE, EDMUND J., B.S., ... 1898.
Care of The Fiberloid Company, 636 Broadway and 340 West 88th Street, New York City.

LEVY, ALBERT LINCOLN, E.M., ... 1890.
149 Franklin Street an4 810 Lexington Avenue, New York City.

LEWIS, CLARENCE MCKENZIE (Life Member), C.E., . 1898.
Engrg. Dept. B. & O. S.-W. R. R., Cincinnati, and 953 Burton Ave., Avondale, Cincinnati, O.

LIBAIRIE, EDWARD WILLIAM, C.E., ... 1894.
150 W. 49th Street, New York City.

In charge Riverside Drive Viaduct construction, 1899.

LIEBMANN, ALFRED, C.E., ... 1893.

50 Broadway, and 38 E. Seventy-second Street, New York City, Member of Firm of R. W. Hildreth & Co.

LIGHTHIPE, WILLIAM WILSON, E.E., ... 1898.

Constr. Engr. Sprague Elevator Co., 3 Arlington Street, Boston, Mass., and 52 Broadway, New York, N. Y.

LILLIENDAHL, ALFRED WHIPPLE, E.M. (Life Member), 1883.

Superintendent, Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico, and Lakewood, N. J.

1883–85, Assistant Supt. Aurora Smelting and Refining Co., Aurora, Ill. 1885-87, Assistant Supt. Grande Milling and Refining Co., Guanajuato, Mexico. 1888-97, Superintendent of the Mazapil Copper Co., Ltd., Concepcion del Oro, Zacatecas, Mexico. Superintendent Coahuila and Zacatecas Railroad.

LILLIENDAHL, FRANK ARMSTRONG, E.M., . . . 1891.

Assistant Superintendent and Metallurgist Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico (via Laredo, via Saltillo).

1891–97, as above.

LILLIE, SAMUEL MORRIS, E.M., ... 1874.

328 Chestnut Street, Philadelphia, Pa.

1874–75, Chemist, Kings County Refining Co., Green Point, L. I., 1876–85 Chemist, Franklin Sugar Refinery, Philadelphia, Pa. 1886–87, Sugar Engineer and Chemist. 1888–90, Vice-President and Manager of "The Sugar Apparatus Manufacturing Co." a company organized under the laws of Pennsylvania, to be operated under his patents. 1891, President of said Company.

LIPPS, HENRY, JR., C.E., ... 1888.

Elliott Avenue, Williams Bridge, New York City.

From July, 1888, to August, 1889, Assistant Engineer Maintenance of Way Dept. R. & D. R. R., W. N. C. & Va. Mid Div. August, 1889, to January, 1890, Supervisor Track, N. C. Div. R. & R. R. January, 1890, Engineer Maintenance of Way, N. C. Div. R. & D. R. R.

LITTLE, WILLARD PARKER, E.M., PH.B., . . . 1881.

Little & O'Connor, Architects, Astor Court Building, 20 West Thirty-fourth Street, New York City.

LIVINGSTON, ARCHIBALD ROGERS, C.E., . . . 1891.

20 North Washington Square, New York City.

1891–96, in employ of Lackawanna I. & S. Co., Scranton, Pa. June, 1896, to February, 1898, with E. D. Smith & Co., Contractors at Niagara Falls, N. Y. Until June, 1898, with Long Island R. R. June, 1898, to January, 1899, Captain First Regiment Vol. Engineers serving in Puerto Rico. February, 1899, to July, 1899, in South America.

LONGACRE, LINDSAY B., M.E., B.D., ... 1892.

595 Lexington Ave., New York City, and Spuyten Duyvil, N. Y.

Graduated with class of 1896, Drew Theological Seminary.

LORD, FREDERICK REUBEN, C.E., ... 1892.
Member of Firm, F. J. Lord & Co., Steamship Agents and Ship Builders, 27 William Street, New York City. and Stapleton P. O., Richmond Co., N. Y.

LOVE, EDWARD GURLEY, A.M., PH.B., PH.D., . . 1876.
Analytical and Consulting Chemist, Gas Examiner, Department Public Works, 122 Bowery, and 80 East 55th Street, New York City.

LOWENSTEIN, JOREPH, PH.B., ... 1896.
205 Belmont Avenue, Newark, N. J.

LOWENTHAL, MAX, E.E., ... 1897.
Room 1257, 11 Broadway and 153 E. 92d Street, New York City.
From 1894 to 1898, Instructor in Mechanical Drawing in the evening schools of The General Society of Mechanics and Tradesmen. 1897-98, Instructor in Electrical Engineering in The United Correspondence Schools, 156 Fifth Avenue, New York. Formerly Editor of *The Technical Journal*. 1898, Asso. Editor *The Electrical Engineer*. 1899, Member of firm Boerner & Loewenthal, later Superintendent of Osterberg & Sutton, Cons. Engrs., 11 Broadway, New York.

LOWTHER, C. M., E.E., ... 1898.
Crocker-Wheeler Co., Ampere, N. J., and 36 Riverside Drive, New York, N. Y.

LUDLAM, FRANK (Associate), ... 1895.
Department of Buildings, 220 4th Avenue, and 8 West 16th Street, New York City.
1896, with Hines & La Farge and since January, 1897, connected with Dept. Buildings, New York City.

LUDLOW, EDWIN, E.M., ... 1879.
Superintendent of Mines, Choctaw, Oklahoma & Gulf R. R., Hartshorn, Indian Territory.
1879-81, Assistant Engineer in charge of hydrographic work on Delaware River under U. S. Engineer. 1881, Assistant Engineer Mexican National Railroad, Mexico. 1882-89, Assistant Superintendent, then Superintendent, for Pennsylvania Railroad coal mines at Shamokin, Pa. 1889, to date, Superintendent of Mines, Choctaw Coal and Railroad Company, Hartshorn, Indian Territory.

LUQUER, LEA MCILVAINE, C.E., PH.D. (1894), . . 1887.
Tutor in Mineralogy, Columbia University, and 321 West 80th Street, New York City.
Summer of 1897, Assistant in Geodetic Surveying with Professor Rees. Summer of 1897, Assistant in Surveying with Professor Munroe. Summer of 1888, Assistant in Geodetic Surveying with Professor Rees. 1887-90, Fellow in Mineralogy, School of Mines, 1890, Assistant in Mineralogy, School of Mines. 1891 to date, Tutor in Mineralogy, Columbia University. 1895-96, Lecturer and Instructor in Mineralogy during absence of Professor Moses in Europe.

LUQUER, THATCHER TAYLOR PAYNE, C.E., E.E. (1893), 1889.
New York Telephone Co., 15 Dey Street, New York City.

1890, Fellow in Engineering. 1890–91, Fellow in Surveying and Practical Mining. 1891, Assistant in Mining, Columbia University School of Mines. 1892 with H. Ward Leonard & Co., New York City. 1893, Engineer, Union Electric Co., New York City. 1894, Engineer Fibre Conduit Company, New York City. 1895, Engineering Dept. Met. Tel. and Tel. Co., and 1896, Engineering Dept. New York Telephone Co.

LUSK, GRAHAM, A.M., PH.B., PH.D., ... 1886.
University and Bellevue Hospital College, and 47 East Thirty-fourth Street, New York City.

1887–88, Student at Munich. 1889, Student at Munich; also at Bellevue Hospital Medical College, New York. 1890, studied at Bellevue; afterwards in Munich. 1891, studied in Munich and was later appointed Instructor of Physiology at the Yale Medical School. 1892, Assistant Professor of Physiology. 1895, Professor of Physiology. 1896, contributed the chapter "The Chemistry of the Animal Body" to the American Text-book of Physiology. 1897, Professor of Physiology at the Yale Medical School. 1898, appointed Professor of Physiology, New York University and Bellevue Hospital Medical College.

LYDECKER, IRVING SMITH, E.M., ... 1898.
Care of Columbus and Hocking Coal Co., New Straitsville, Ohio, and 562 E. 155th Street, New York City.

Summer of 1898, Draughtsman Arkansas Valley Smelting and Refining Co., Leadville, Colo. October, 1898, to October, 1899, General Assistant to A. O. Ihlseng (zinc mine operator), Jopkin, Mo. 1900, Assistant Engineer Columbus and Hocking Coal Co.

LYMAN, FRANK, A.B., M.E., ... 1878.
31 Burling Slip, New York City, and 39 Remsen Street, Brooklyn, N. Y.

Treasurer The Low Moor Iron Co. of Va.

M.

MCCAFFERY, RICHARD S., E.M., ... 1896.
316 E. 124th Street, New York City.

MCCLELLAND, J. BRUCE, B.S., A.M., ... 1897.
2 West 47th Street, New York City.

MCCONWAY, WILLIAM, JR., E.M., ... 1896.
The McConway & Torley Co., 48th Street, and A. V. Ry. and 2834 Bedford Avenue, Pittsburg, Pa.

MCILHINEY, PARKER C., A.M., PH.D . . . . 1892.
Columbia University, and 408 Third street, Brooklyn, N. Y.

Summer of 1892, Chemist Fibre Pipe Co. 1893–94, Hon. Asst. in Assaying. 1894, Asst. in Metallurgy. Since 1894, associated as Chemist with Mr. Louis C. Tiffany in his artistic work in glass and metal. Also, engaged in general chemical practice at 145 E. 23d Street, N. Y.

McKENNA, CHARLES FRANCIS, PH.B., . . . 1883.

221 Pearl Street, and 155 West 91st Street, New York City.

1883–84, Chemist, Havemeyer Sugar Refining Co., Jersey City, N. J. 1885–86, Chemist, Cambria Iron Co., Johnstown, Pa. 1887-90, Engaged in the manufacture of lime for gas purification, Edgewater Lime Works, Edgewater, N. J. 1891–93, with Jas. J. McKenna & Bro., Founders, New York City. 1893, Associated with Dr. Gideon E. Moore, New York City, as Director of the Laboratory of Physical Testing. 1895–97, Chemist to the Passaic Zinc Co., Practising as consulting chemist and inspector of materials.

McKIM, ALEX. RICE, B.S. (Mass. Inst. Tech.), A.M., . 1897.

106 East 23d Street, and University Club, New York City.

Graduated as Civil Engineer Mass. Inst. of Technology (B. S.), Technische Hochschule zu Berlin, two years. School of Architecture at Columbia University (A. M.). Old Colony Railroad, Construction. Edge Moor Bridge Works, Bridges. Berlin Bridge Co., Building Construction. J. B. & J. M. Cornell, Building Construction. Since May, 1895, Consulting and Expert Architectural Engineer.

McKIM, ROBERT ALBERT, C.E., ... 1884.

Room 213, 280 Broadway, and 34 West 91st Street, New York City.

Assistant Engineer on New Croton Aqueduct. (Entered Aqueduct Engineer Corps as Chainman, in February, 1885.)

McKINLAY, WM. BRADFORD, E.M., ... 1895.

Address unknown. If any member knows it will he please advise the Secretary of it?

Assistant at Pelican-Dives Mine Georgetown, Colo., October-December, 1895. Mine Clerk at Peerless Coal Mine, Aguilar, Colo., December, 1895, to February, 1896. General Assay Office at La Bella, Toas Co., New Mexico, May to November, 1896. March, 1897-99, Assistant Engineer Playa de Oro Mining Co., Ecuador, S. A.

McLAUGHLIN, CHARLES SWAIN, PH.B., . . . 1884.

890 Broadway, New York City.

MACHEN, CHARLES HUDSON, E.E., ... 1899.

Met. Street Ry. Co. Power House, 50th Street and Sixth Avenue, and 150 W. 82d Street, New York, N. Y.

MACHEN, HENRY BENNETT, C.E., ... 1898.

Room 600, Grand Central Station, and 150 W. 82d Street, New York, N. Y.

Instrument man, Am. Mining Co., Mineral City, Va. Draughtsman, Norwich Union Fire Insurance Co. and Chainman N. Y. C. & H. R. R. R.

MacKAYE, HAROLD STEELE, C.E., ... 1887.

29 Liberty Street, and 225 West 106th Street, New York City.

Three months' work in New York Harbor in Army Corps of Engineers. One year's employment in the Office of Patent Solicitors. 1889-92, acting as Fourth Assistant Examiner of the U. S. Patent Office. Since July, 1892, Patent Counsel for Westinghouse Electric and Manufacturing Co. In independent practice as patent lawyer since November 1, 1896.

MACLAY, JAMES, C.E., ... 1888.
Instructor in Mathematics, Columbia College, and 87 Union Street, Newark, N. J.

MACY, CHARLES A., 2d, E.M., ... 1895.
Union Club, 1 West 21st Street, and 208 W. 45th Street, New York, N. Y.

MAHONY, ARTHUR STUART, E.M., ... 1889.
51 West 94th Street, New York City.

1890, First Assistant General Manager of the New Birmingham Iron and Land Co. 1891, Treasurer of the same company, also Chemist to the Tassie Belle Furnace, Texas. 1893, contractor.

MALUKOFF, A. J., ... 1893.
Department of Bridges, 177th Street and 3d Avenue, and 72 West 131st Street, New York City.

MANNHEIM, HERMANN CHARLES, E.M., ... 1887.
76 Warren Street, New York, N. Y.

MANNHEIM, PAUL AUGUST LOUIL, E.M., ... 1885.
Smelter, Montana Smelter, Cascade Co., Montana.

MARIE, LEON, E.M., ... 1885.
Majestic Hotel, New York City.

MARSH, JOHN ROLLIN, E. M., ... 1887.
Address unknown. If any member knows it will he please notify the Secretary of it?

MARTIN, EDWARD WARD (Associate), ... 1877.
Chemist, Board of Health, 301 Mott Street, New York City.

MARTIN, L. TROWBRIDGE, E.E., ... 1897.
114 East 36th Street, New York City.

MASSA, CHARLES GRISWOLD, C.E., ... 1889.
Fort Lee, N. J.

Since October, 1889, on varied engineering work, including: Topographical Survey, Greenwood Lake, N. Y., 1889; Structural Steel Shop Inspection with R. W. Hildreth & Co., at Phœnixville, Pa., 1890, and at Harrisburg, Pa., 1894; Construction Lehigh Valley Ry. Extension, Geneva, N. Y., 1890; Street Railway Construction, Allegheny, Pa., 1890-91; R. of W., Maintenance, Construction, Northwestern System, Penna. Lines. 1891-93; Construction, Masonry Dam, etc., Newton, N. J., Waterworks, 1895. On Chatham, N. J., Waterworks, 1897, and similar work to date.

MASSA, LOUIS FERDINAND, C.E., ... 1890.
Fort Lee, N. J.

October, 1890-92, shop practice, Maryland Steel Works, at Sparrow's Point, Md., as follows: October, 1890, to July, 1891, Machine-shop practice. July, 1891, to September, 1891, Bessemer Mill Construction. September, 1891, to September, 1892, Bessemer Rail-mill and Roll-house; Mechanical and Metallurgical

Engineering. October, 1892-93, Post-graduate Electrical Engineer at Columbia College. February, 1894, to date, Electric Engineering, Construction and Constructing.

MASTERS, H. K., E.M., ... 1894.
Nichols Chemical Co., Laurel Hill, L. I., N. Y., and 167 Clinton Street, Brooklyn, N. Y.

MATHEWS, JOHN ALEX., B.S., M.S. (Washington and Jefferson), A.M., PH.D., ... 1895.
College of Physicians and Surgeons, 437 W. 59th Street, New York City, and 4 First Place, Brooklyn, N. Y.

Assistant in Assaying, Columbia University, 1896-97. Fellow in Chemistry, 1897-98. Tutor in General Chemistry, 1898 to date. Fellow of the Chemical Society, London ; Member of the American Chemical Society.

MATHIS, THEOPHILUS SMITH, E.M., ... 1879.
49 South Main Street, and 52 East Ninth Street, Salt Lake City, Utah.

From January, 1890, to February, 1891, Assistant Draughtsman U. S. Surveyor General's Office, Salt Lake City, Utah. From February, 1891, to August, 1893, Chief Draughtsman of Mineral Division of said office. From August, 1893, to date, engaged in General Mining Engineering Work.

MAYER, RALPH EDWARD, C.E., ... 1879.
Instructor in Mechanical Drawing, Columbia University, New York City.

MEISEL, C. F. A., PH.B., ... 1892.
44 Strong Place, Brooklyn, N. Y.

1892-93, 1st Asst. Chemist National Lead Co. 1893-94, Chemist, International Phosphate Co. 1895-97, Examiner Chemist, U. S. Laboratory.

MEISSNER, CARL AUGUST, PH.B., ... 1880.
Dominion Iron & Steel Co., Ltd., Sydney, Cape Breton, Canada.

One year, Assistant Chemist Joliet Steel Co. Three years, Chemist and Assistant Superintendent Brier Hill Iron and Coal Co., Youngstown, Ohio. One and a-half years, Head Chemist Joliet Steel Co. Three years, Manager Sterling Iron and R'wy Company, Sterlington, N. Y. At present, Vice-President and General Manager of the Vanderbilt Steel and Iron Company, Birmingham, Ala., after having personally organized this company. President Jefferson County Mining and Quarrying Company.

MELLISS, D. EARNEST, A.M., PH.D. (Associate), . 1868.
Consulting Engineer, 524 Sacramento Street, San Francisco, Cal.

Student regular course, three years, School of Mines. Afterwards, two and a-half years University of Göttingen, graduating Ph.D., in 1869. One year at University of Vienna. Since then, constantly occupied in civil and mining engineering. In 1873 was Chief Engineer in Charge of Topographical and Geological Survey of Guanocaste and Nicoya for the Costa Rican Government. In 1881, Consulting Engineer to the Pacific Gas Light Company, of San Francisco, and in

its interests studied the different gas-making systems in the United States, England, France and Belgium. Have made plans, reported upon and erected numerous gold, silver, copper and lead mines. Planned the Union Iron Works of San Francisco, and superintended their construction ; also, the Arctic Oil Works and several other industrial establishments on the Pacific Coast. Designed and built the Mazatlán Water Works, in Mexico; The Hydraulic Press Brick Works, of California, the largest establishment of its class on the Pacific Coast. Four years in Central America and Mexico. Was Administrator of San José de las Bocas and Consulting Engineer to Guadalupe de los Reyes, the most successful silver mine of Sinaloa. Now Consulting Engineer in San Francisco, and particularly occupied in that capacity for the Olympic Salt-Water Co., whose works are now being erected under his supervision and according to his plans. Planned and built the Olympic Salt-Water Co.'s Works, San Francisco, Calif. 1894–97, Superintendent of Works, San Francisco, New City Commission. Fall, 1897, investigating hydraulic questions in Venezuela.

MENLINE, ISAAC, C.E., ... 1898.

Care Erie R. R. Co., Meadville, Pa.

Since October, 1898, to 1899, with the Johnson Co., Lorain, Ohio.

MERRILL, FREDERICK JAMES HAMILTON, PH.B., PH.D., 1885.

State Museum, and 95 Washington Avenue, Albany, N. Y.

1885–87, Assistant on the Geological Survey of New Jersey. 1886–90, Fellow in Geology, Columbia College School of Mines. 1890–93, Assistant State Geologist of New York. 1890–94, Assistant Director of the New York State Museum. 1892–93, Director of the Scientific Exhibit of the State of New York at the World's Columbian Exposition. 1894 to date, Director of the New York State Museum, Albany, N. Y. 1898 to date, State Geologist of New York.

MERRITT, JAMES HAVILAND, PH.B., A.M., . . . 1880.

3 Monroe Place, Brooklyn, N. Y.

1881–88, Chemist to the Bradley White Lead Co. In 1889 entered the School of Mines as Post-graduate in the course of Architecture. 1892–93, Architectural Study.

MERZ, EUGENE, E.M., ... 1892.

Box 216 and 143 Littleton Avenue, Newark, N. J.

Assistant Superintendent American Ultramarine Works.

MESEROLE, WALTER MONFORT, C.E., ... 1881.

189 Montague Street, and 2789 Atlantic Avenue, also 288 Hancock Street, Brooklyn, N. Y.

1881, Transitman and Topographer Continental Railway Co. 1881–83, Assist. Eng. in Construction, N. Y., West Shore and Buffalo Ry. 1884–85, Division Engineer Maintenance of Way. 1885, Chief Engineer Catskill Mountain and Cairo Railway. 1885, in charge Topographical Survey for Kings County Charities Commission. 1886 to date, in General Practice, located at Brooklyn, N. Y. Specialties : Improvement and Development of Real Estate and Surveying for Legal and Construction Purposes ; City Surveyor of the City of Brooklyn ; Chief Engineer South Brooklyn R. R. and Terminal Company, German-American Improvement Company and Hancock and State Line Railway Company. Erie and

Central New York Ry. Co. Eng. Commission Atlantic Avenue Improvement, Brooklyn, N. Y.

MESSITER, E. H., C.E., ... 1894.

Arkansas Valley Smelting Co., Leadville, Colo., and 320 West 109th Street, New York City.

1889, Draughtsman New Croton Aqueduct. 1891 (Summer vacation), Draughtsman Mfg. Investment Co., Madison, Me. Mill Construction, June, 1894, to November, 1894. Inspector under Wm. Barclay Parsons, C.E., November, 1894-June, 1895, Engineer Guggenheim Smelting Co., Perth Amboy, N. J. June, 1895, to January, 1896, Chief of Party, Surveys for Rapid Transit Commission, New York City. January, 1896, to November, 1896, Engineer Guggenheim Smelting Co., Perth Amboy, N. J. November, 1896, to April, 1897, Engineer Philadelphia Smelting and Refining Co., Pueblo, Col. April, 1897, to date, Engineer Arkansas Valley Smelting Co., Leadville, Col.

MEYER, HERMAN HENRY BERNARD, E.M., . . 1885.

Brooklyn Union Gas Company, Nevens and Degraw Streets, and *for mail* 844 Putnam Avenue, Brooklyn, N. Y.

Surveying, Field and Office Work at Pelham Park, Westchester Co., July to November, 1885. December, 1885, to date, Engineer for Oregon Iron Works, New York, designing and erecting machinery for manufacturing illuminating gas.

MIDDETON, JOHN, C.E., ... 1887.

2789 Atlantic Avenue, and 189 Montague Street, Brooklyn, N. Y.

1888-97, Surveyor Assistant to W. M. Meserole, C.E.

MILLER, CHARLES LEWIS, E.M., ... 1885.

General Superintendent American Steel Wire Co., Tradesman's Bldg., and 6200 Howe Street, Pittsburg, Pa.

1886, Assistant Chemist Edgar Thomson Steel Works, Braddock, Pa. 1886-87, Chemist and Assistant Superintendent Carbon Iron and Pipe Co., Perryville, Pa. 1887-90, Superintendent The Missouri Furnace Co., St. Louis, Mo. 1890-96, Superintendent Blast Furnaces at Union Works of Illinois Steel Co., Chicago, Ill. Since August, 1896, General Superintendent Union Works, Ill. Steel Co., Chicago, Ill. 1897-99, General Superintendent Joliet Works, Ill. Steel Co. 1899, General Superintendent American Steel and Wire Co.

MILLER, CHARLES WATTS, E.M., ... 1884.

Assistant Manager Silver Lake Mines, Silverton, Colo.

1884-85, Metallurgical Engineer Hecla Bronze and Iron Works. 1885-86, Assayer and Chemist, Aspen, Col. 1886-91, Mining Engineer and United States Deputy Mineral Surveyor, Aspen, Col. General mining engineer business. 1898, Assistant Manager Silver Lake Mines, Silverton, Col.

MILLER, EDMUND HOWD, PH.B., A.M. (1892), PH.D., (1894), ... 1891.

Instructor in Analytical Chemistry and Assaying, Columbia University, and West Nyack, Rockland Co., N. Y.

1891-94, Assistant in Assaying. 1894-97, Tutor in Analytical Chemistry and Assaying. 1897, as above.

MILLER, RUDOLPH PHILIP, C.E., ... 1888.

141 East Fortieth Street, New York City.

1888-90, Assistant to E. M. W. 1890-94, Supervisor R. & D. Railway till April, 1894. August to November, 1894, with W. S. Miller, Builder, New York City. November, 1894, to October, 1895, with Long Island R. R. as Transitman and Assistant. December, 1895, to date, with Department of Buildings, New York City.

MILLER, SAMUEL O., C.E., ... 1895.

Columbia University, New York City, and West Nyack, N. Y.

From June to September, 1895, field and office work for Ramapo Water Co. January to March, 1896, engaged in Mine Surveying for the Sterling Iron and R. R. Co., Sterling, N. Y. From March, 1896, to date, in the employ of the Department of Buildings of New York City. 1897-98, Assistant Engineer, Department of Buildings, New York City. Assist. in Mech. Engineering, Columbia University.

MOELLER, EDGAR J., PH.B., ... 1895.

3 River View Terrace, New York City.

MOLDEHNKE, RICHARD GEORGE GOTTLOB, E.M., PH.D., 1895.

Pa. Malleable Co., Park Bldg., and McCandlers and Stanton Avenues, Pittsburg, Pa.

1885-87, Three Summer seasons with United States Coast and Geodetic Survey, New York and Philadelphia Harbors and Cape Cod, Mass., *Hydrographic Work*, Triangulation, Levelling, etc. 1885-86, Winter, nine months, *Sanitary Engineering*, Inspector, etc., New York Association for Improvement of Condition of Poor. 1887-89, *Electrical Engineering*, five months Mining Engineer Sprague Electric Railway and Motor Co., seven months Mechanical Engineer Crocker-Wheeler Motor Co., five months experimenting on patents taken out. 1889, Manufacturing for myself. Specialty in Machinists' Tools. 1889-90, Professor Mechanical and Electrical Engineering, Michigan Mining School, Houghton, Mich. 1890-99, Metallurgist, McConway & Torley Co. 1899, Organized the Pa. Malleable Co. taking position of Supt., also consulting Metallurgist, specially iron and steel. Expert in Malleable Castings.

MONELL, JOSEPH THOMPSON, C.E., ... 1889.

236 W. Twenty-second St., New York City.

1891, Electrical Engineering, Curtis Electrical Mfg. Co. 1892, Tutor in Astronomy, Columbia College.

MONKS, RICHARD A. (Associate), ... 1894.

130 Water Street and 71 Lexington Avenue, New York City.

MONTENEGRO, MANUEL RAFAEL, E.M., ... 1890.

539 W. Twentieth Street, New York City.

1890, Spiral Weld Tube Company, East Orange, N. J., and studying machine-shop practice. 1891-92, engaged in the formation of mining companies. 1892 to date, Assistant Superintendent Oregon Iron Works, New York City.

MORA, MARIANO LUIS, C.E., ... 1891.

General Electric Company, Foreign Department, 44 Broad Street, and 63 West 70th Street, New York City.

Graduate Post-graduate Course Electrical Engineering, 1894.

MORAN, DANIEL EDWARD, C.E., ... 1884.
John Monks & Son, 130 Water Street, and 71 Lexington Avenue. New York City.

MORGAN, WILLIAM FELLOWES, A.B., E.M. (Life Member), 1884.
Brooklyn Bridge Freezing and Storage Co., Arch 4, Brooklyn Bridge, New York City, and Short Hills, N. J.

1884–88, Banking and Brokerage. 1888 to date, Pres. Harrison Cold Storage Co.

MOSLEY, RICHARD KELLER, PH.B., ... 1889.
Architect, Room E, 22 Produce Exchange Building, New York City, and 139 Glenwood Avenue, East Orange, N. J.

From June, 1889, to January, 1893, worked as Draughtsman in the Office of L. J. O'Connor, Carrére & Hastings, and Richard M. Hunt, of New York, and Benj. Silliman, of Yonkers, N. Y. Since January, 1893, practicing Architecture independently at the above address.

MOSES, ALFRED JOSEPH, E.M., PH.D., ... 1882.
Professor Mineralogy, Columbia University School of Mines.

1882–85, Assistant in Mineralogy, School of Mines. 1885–90, Instructor in Mineralogy and Metallurgy. 1890–97, Adjutant Professor of Mineralogy.

MOSES, PERCIVAL ROBERT, E.E., ... 1895.
35 Nassau Street, and 46 West 97th Street, New York City.

MULFORD, ROBERT, E.M., ... 1884.
Manager Fraser & Chalmers, 80 Broadway, New York City, and 144 S. Second Avenue, Mt. Vernon, N. Y.

1890, Assistant Superintendent Rio del Oro Gold Co., Argentine Republic, S. A. 1891, Honduras. 1893, General Manager of The Kanimpoo Gold Mining Co., Limited, of Georgetown, Demarara, British Guiana, and am now in the employ of Fraser & Chalmers.

MÜLLER, GEORGE, PH.B., ... 1887.
634 East One Hundred and Thirty-ninth Street, New York City.

MULLER, JULIUS, E.E., ... 1899.
Sprague Elec. Co., Wattessing, N. J., and 418 West 154th Street, New York, N. Y.

MUNROE, HENRY SMITH, E.M., PH.B., ... 1869.
Professor of Mining, and Member of the University Council, Columbia University, New York City.

1869–70, Post-Graduate Student in Chemistry and Economic Geology, School of Mines. 1870–71, Assistant Geologist Ohio State Geological Survey. 1870–72, Assistant Chemist, Department of Agriculture, Washington, D. C. 1872–75, Assistant Geologist and Mining Engineer, Geological Survey of Yesso, Japan. 1875–76, Professor of Geology and Mining, University of Tokio, Japan. 1877–91, Adjutant Professor of Surveying and Practical Mining, and 1891, Professor of Mining, School of Mines, Columbia University, New York City. 1884–85, Manager, and 1890–92, Vice-President American Institute Mining Engineers. 1895, to date, Member of the University Council, and 1897–99, Dean of the Faculty of Applied Science, Columbia University.

MUNROE, OTIS MORTIMER, PH.B., ... 1879.
Banker, De Soto, Mo.

MUNSELL, CHARLES EDWARD, PH.B., PH.D., . . 1878.
F. W. Devoe & C. T. Raynolds Co., 110 Horatio Street, New York City, and Rye, N. Y.

November, 1878, with E. A. Foote, Mineral Dealer, Philadelphia. March, 1879, with T. A. Edison, Menlo Park, N. J. May, 1879, Chemist, Bushwick Chemical Works, Brooklyn, N. Y. October, 1879, Stencilographer and Celestyper, School of Mines, N. Y. January, 1880, to December, 1885, Milk Inspector, New York City Health Department. July, 1881, to May, 1883, State Milk Inspector, New York State Board of Health. 1886 to date, Analyst and Assistant Chemist, F. W. Devoe and C. T. Raynolds Co., New York City. Specialty, Paints and Colors.

N.

NAVARRO, JOHN ADALBERT, C.E., ... 1880.
Seminario No. 1, Mexico City, Mexico, and care Mexico Consul-General, 35 Broadway, New York City.

1881–82, Civil Engineering Course in Polytechnium, Hanover, Germany, 1882–84, Mexican Government Commissioner to study railway systems of Europe. 1885–86, Railroad Inspector in Interoceanic Railroad, Mexico. 1886–87, Assistant Compiler of Memoir, published by Department of Public Works (*Fomento*), Mexico. 1887 to date, Engineer in charge of Surveys and Representative in Chiapas of the Mexican Land and Colonization Co.

NESMITH, JAMES, E.M., ... 1879.
256 Henry Street, Brooklyn, N. Y.

NEBROUGH, WILLIAM, A.B., E.M., ... 1884.
Evanston, Wyoming, and 122 West 34th Street, New York City.

NICHOLS, RALPH, E.M., C.E., ... 1877.
Mgr. Great Boulder Perseverance Mfg. Co., Kalgoorlie, W. Australia.

1878, Ore Sorter, Hukill Mine, Idaho Springs, Colo. Later, Assistant in F. E. Brown's Civil and Mining Engineering office, Georgetown, Colo. Later, Assayer and Chemist La Plata M. and S. Co., Leadville, Colo. Appointed U. S. Deputy Mineral Surveyor in 1879. 1879–82, Civil and Mining Engineer at Leadville, Colo., with the following firms: Page, Nichols & Co., and Nichols & Dunham, Superintendent Farewell Con. Mining Co.'s Gold Mill at Independence, Colo. Superintendent of the Big Pittsburg Cons. Mining Co., Leadville. 1883, Superintendent of the Viola Mining and Smelting Co. Later General Manager of same until 1891. Since then have been mining and working mines on lease. Examined mines in Colorado, Idaho, Nevada and Mexico. 1894, General Superintendent The Comstock Tunnel Co. Interested in Mines in Colorado and Idaho, and am working mines in Idaho under lease. Have acted as ore buyer for the Cons. Kansas City S. and R. Co. 1899, representing the Globe S. and R. Co. in Nevada.

NOLAN, THOMAS, B.S. (Univ. of Rochester, N. Y.), PH.B., 1884.
Professor of Architecture, Univ. of Missouri, Columbia, Mo.

Practicing Architect, Rochester, N. Y., 1884-87. Student of Architectural and Engineering works in Europe, 1888-89. Student at Paris in Ecole des Beaux Arts, Atelier Daumer, 1889. 1890-97, practicing Architect, Rochester, N. Y. 1896, made Architectural and Archæological investigations in Greece and Italy. 1897-98, made special investigations in Engineering and Architecture, Columbia University. 1897-98, practicing Architect, No. 111 Fifth Avenue, New York. 1898-99, member of the faculty of Architecture in University of Pennsylvania. 1899, Professor of Architecture in the University of Missouri, Columbia, Mo.

NORRIS, ROBERT VAN ARDSDALE, E.M., . . . 1885.
Assistant Engineer P. R. R. Department of Anthracite Coal, Room 28, First National Bank Building, and 24 S. Franklin Street, Wilkesbarre, Pa.

1885, Assistant in Practical Mining and Surveying, School of Mines. U. S. Inspector of Dredging, in charge of Maurice River Improvement, Millville, N. J., 1886, Chemist, Herman Behr, Manufacturer of Colors, Brooklyn, N. Y. June, 1896, to date, Assistant Engineer, Pennsylvania Railroad Department of Anthracite Coal Collieries. Specialty, Mechanical Engineering of Collieries.

NORTON, LUCIEN HOLLEY, E.M., ... 1886.
Apartado 109, Montersey, N. L., Mexico.

1887-90, Engineering Office, N. Y., N. H. & W. R. R. Experience in Railroad Construction, Location and Preliminary Surveys, Office Works and General Surveying. 1890, Assayer and Engineer to West Indian New Gold Mining Corporation, San Domingo, West Indies. Experience in Free Milling of Gold ores, Assaying, Surveying, etc. January, 1891-92, Assayer for Daly Mining Co., Park City, Utah. Experience in Assaying, General Analyses. Also Leaching of Silver ores by the Russel Process. 1892-99, Penna. Smelting Co., Sanday, Utah.

NOYES, JAMES ATKINS, PH.B., A.B. (Harvard, '83),
(Life Member), ... 1878.
71 Sparks Street, Cambridge, Mass.

Editor Quinquennial Catalogue, Harvard University.

NOYES, WILLIAM SKAATS, E.M., ... 1875.
R. T. Mills Building, Shafter, Presidio County, Texas, and 2023 Summit Street, Oakland, Calif.

1877-79, Assayer for McCrackin Mining Co., Mohave Co., Arizona. 1879-81, Foreman of Bodie Mill, for Bodie Coal Mining Co., Bodie, Cal. 1881-83, Examining Mines for San Francisco Capitalists. 1883 to present time, Superintendent of Presidio Mining Co., and The Cibilo Creek Mill and Mining Co., Shafter, Presidio Co., Texas.

NYE, ALVAN CROCKER, PH.B., ... 1884.
Hayden Furniture Co., 1 West Thirty-fourth Street, and 1143 Lexington Avenue, New York City.

1884-85, Draughtsman C. C. Haight, Architect. New York City. 1885-90, Designer and Head Draughtsman, Herter Brothers, New York City. 1898 to date, Furniture Designer and Architect, the Tiffany Glass Co., New York City. 1892, Chief Designer as above.

O.

O'CONNOR, MICHAEL JOSEPH, E.M., PH.B., . . 1881.
Little & O'Connor, Architect (1884) the Astor Court Building, 20 West Thirty-fourth Street, New York City.

O'CONNOR, THOMAS DELVIN, P.HB., ... 1881.
Aldrich Court, 45 Broadway, Room 91, and 12 East Forty-fourth Street, New York City.

OF, CHARLES, E.M., ... 1896.
Whitewater, B. C., and 802 Prospect Avenue, New York City, N. Y.

OLCOTT, EBEN ERSKINE, E.M., ... 1874.
Mining and Metallurgical Engineer, 18 Broadway, and 38 West Thirty-ninth Street, New York City.

1874-75, Chemist to Ore-Knob Copper Co., in charge of Hunt & Douglas Process. 1875-76, Assistant Supt. Penna. Lead Co.'s Works, Mansfield Valley, Pa. 1876-78, Assistant Supt. Orinoco Exploring and Mining Co., at their Gold Mines in Venezuela. 1878-79, Supt. of the same. 1879-81, Examining Mines in Colorado, Utah, Nevada and California, for New York Investors. 1881-85, Supt. St. Helena Gold Mines, Sonora, Mexico. 1885, opened office in New York, as Consulting Engineer, and since then has been engaged as Consulting Mining and Metallurgical Engineer in Peru, Republic of Colombia, Dutch and British Guiana, Mexico, British Columbia, Ontario, New Brunswick and the United States. 1895, Consulting Mining and Engineer and Genl. Mgr. Hudson River Day Line. Member of the firm Olcott, Fearn & Peele, Consulting Mining Engineers.

ORMSBEE, JAMES JACKSON, E.M., ... 1886.
El Paso Smelting works, El Paso, Texas.

1886-91, Mining Engineer of Tracy City Division of Tennessee Coal, Iron and Railroad Co. 1891-92, Superintendent, Thomas Coal Mines, of Tennessee Coal, Iron and Railroad Co., Whitwell, Tenn. 1892-94, Engineer and Superintendent Sequachee Valley Coal and Coke Co. 1894, Superintendent Poplar Creek Div. Tenn. Coal, Iron and Railroad Co. 1899, Superintendent Tenn. Coal, Iron and Railway Co., Tracy City, Tenn.

OSTERBERG, MAX, E.E., A.M., ... 1894.
27 Thames Street, and 113 East Fifty-sixth Street, New York City.

Summer '84, after graduation : Editor of the *Proceedings* of the Chicago Electrical Congress. Practical shopwork in a dynamo factory. October 1st, Appointed Associate Editor of *Electrical Power*. During season 1894-95 Instructor of Electrical Engineering at the National School of Electricity, at the Y. M. C. A. in New York City, and Stamford, Conn. Fall '94, Reëntered College to pursue post-graduate studies. June, '95, was appointed University Fellow in Mechanics. January, '96, author of *Synopsis of Current Electrical Literature*. Established as Consulting Engineer and Electrical Expert on September 1, 1896.

OSTERHELD, THEODORE W., E.M., ... 1886.

Consulting Engineer, Apartado, No. 38c, Pueblo, Mexico.

Assistant Superintendent of Blast furnaces, P. S. Co., 1886-87. General Foundry Practice, Worthington P. Works, 1887-88. Owners of Foundry and General Iron Works, 1888-89. Vice-President Pendleton Mining Co., and Consulting Engineer, 1889-91, and general Consulting Engineer, Iron and Coal Specialty, and Metallurgist of Iron and Finished Manufacturing. Interval of 1890-91, of the months of December to May, Superintending Construction of Rolling Mill, Southwest Virginia. Specialty Coal and Iron of the Virginias. President of the Southern Reducing Co., Experts, Chemists and Mining Engineers. Locating Engineer C. & M. R. R., Cartagena, 1891-92; Chief Engineer, C. &. Z. R. R., 1893-95, Coahuila, Mexico. 1895 to present date, Consulting Engineer and Member of the Banking Firm, Rosst, Headen & Co., Pueblo, Mexico. Member and Consulting Engineer Banking and Exporting Firm, Rosst, Headen & Co.

P.

PAGE, GEORGE STEPHEN, E.M., ... 1885.

Care Park Bros. & Co., Limited, and 6710 McPherson Street, Pittsburg, Pa.

1885-96, Assistant Chemist Edgar Thompson Steel Works. From July 1, 1886, to date, Manager of Steel Works with Park Bros. & Co., Ltd. Specialty, Manufacture of Open-Hearth and Crucible Steel.

PAINTER, CHARLES ALBERT, E.M., ... 1884.

J. Painter & Sons, Pittsburg, Pa., and 208 Western Avenue, Allegheny City, Pa.

PAINTER, GEORGE EDWARDS, PH.B., ... 1883.

Care of American Steel Hoop Co., 1st National Bank Building, Allegheny City, Pa.

PARKER, ANDREW MCCLEAN, E.M., ... 1880.

Engineer and Superintendent, Shanly & Ryan, Contractors for N. Y. Anchorage New E. R. Bridge, New York.

First Assistant Engineer, Department of Docks, New York City, Engr. and Supt. of Construction N. Y. Anchorage, New East River Bridge.

PARKER, HERSCHEL CLIFFORD, PH.B., ... 1890.

Department of Physics, Columbia University, New York City, and 21 Fort Green Place, Brooklyn, N. Y.

1890-91, Fellow in Physics. 1891-93, Assistant in Physics. 1893-99, Tutor in Physics, Instructor in Electrical Measurements. 1899-1900, Tutor in Physics.

PARKER, RICHARD ALEXANDER, C.E., E.M., . . . 1878.

Consulting Mining Engineer, 320 Sansome Street, San Francisco, Calif., and 8 Congress Street, Boston, Mass.

1878-79, Assistant Superintendent, Montezuma Silver Mining Co., Montezuma-Colo. 1880-81, Surveyor at Georgetown. 1881-82, Chief Draughtsman, Mexican Natl. Cons. Co., Laredo, Texas. 1883-84, Examining Mines in Colorado, Utah and Idaho mainly. 1885-86, Superintendent, Atlanta Hill Gold Co., Ala.

Superintendent of the Big Lode (Gold) Co., Atlanta, Alturas Co., Idaho. 1887, Resident Manager and Agent for Samson Iron Co., Imperial Iron Co., and Barass Iron Co. 1896, General Manager Simmer & Jack, Prop. Mines Ltd., Johannesburg, South Africa. 1897 to date, Consulting Engineer and General Manager California Exploration, Ltd.

PARKS, JOHN RANDOLPH, E.M., ... 1880.
Halena, Mont.
Consulting Mining Engineer.

PARRAGA, CHARLES FREDERICK, C.E. (Life Member), . 1883.
58 William Street, and 145 W. Ninety-seventh Street, New York City.

1883-85, Inspector of Construction of Bridges and Railroad Material in Europe. 1884-86, Railroad Engineer in Colombia, S. A. 1888 to date, General Expert Business. 1881, Delegated from Columbia to the Inter-Continental Railway Commission at Washington, D. C.

PARROT, EDWARD MONROE, E.M., ... 1870.
Ontario, Wayne County, N. Y.

PARSONS, HENRY, C.E., ... 1888.
Secretary and Treasurer, So. Ca. & G. R. R., 15 Broad Street and 1033 Madison Avenue, New York City.

PARSONS, WILLIAM BARCLAY, A.B., C.E., . . 1882.
22 William Street and 51 East Fifty-third Street, New York City.

Previous to graduation served as Assistant Engineer Arnot and Pine Creek Railroad and Blossburg Coal Mine. After graduation entered Maintenance of Way Department of the New York, Lake Erie and Western Railroad. Resigned in 1885 and commenced practice as Consulting Engineer, New York; as such have had charge of much heavy engineering construction. At present Chief Engineer Rapid Transit Commission, New York City.

PATTBERG, OTTO FRED'K, E.M., ... 1898.
639 Pavonia Avenue, Jersey City, N. J., and Stella Mines, DeKalb Junc., St. Lawrence Co., N. Y.

1898, Asst. Supt at the Aurora Works, Chicago and Aurora Smelting and Refining Co. up to August 1, 1899. Then spent three months in Joplin, Mo., Zinc and Lead District.

PAYNE, CLARENCE QUINTARD, ... 1882.
President Payne Separator Co., 99 John Street, New York City, and Stamford, Conn.

PECK, STAUNTON BLOODGOOD, C.E., E.M., . . 1886.
Link Belt Machinery Co., Thirty-ninth Street and Stewart Avenue, Chicago, Ill., and 111 East Thirty-fourth Street, New York City.

One and a-half years Mechanical Engineer, Burr & Dodge, Philadelphia. Two Years Assistant Chief Engineer Link Belt Engineering Company, Philadelphia. Since 1888, Assistant Chief Engineer Dodge Coal Storage Company. Since 1890 and at present, Chief Engineer Link Belt Machinery Company, Chicago. Specialty, handling materials in bulk or package and power transmissions.

PEELE, ROBERT, E.M., ... 1883.

"The Monterey," One Hundred and Fourteenth Street, and Morningside Park, New York City.

1883, Assayer, Designolle Reduction Works, Charlotte, North Carolina. 1883–84, Assayer and Assistant Superintendent Silver King Mining and Milling Co., Montezuma, Colorado. 1884–86, Foreman, Dry-crushing and Amalgamating Silver mill, Silver King Mining Co., Pinal, Arizona. 1886, went to England to examine systems of sewage disposal used in inland towns. 1887, Professional work as assistant, in New York and Arizona. 1888, Examining gold mines in Republic of Colombia, S. A. Superintendent Mudsill Mining Co., Ltd., Fairplay, Colorado. Examinations and Ore-testing on Copper and Tin Properties, New Mexico and North Carolina. 1889, Examining Gold Placers, Dutch Guiana, South America. 1889–90, Superintendent Oregon Gold-mining Co., Cornucopia, Oregon. 1890-92, Examining Silver, Tin, and Gold mines, in Peru, Bolivia, and Republic of Colombia, S. A., for the Peruvian Exploration Syndicate, Ltd., London, and Lima, Peru. 1892, Adjunct Professor of Mining, Columbia University. Also, since 1896, member of firm Olcott, Fearn & Peele, Consulting Mining Engineers, 18 Broadway, N. Y.

PELLEW, CHARLES ERNST, E.M., ... 1884.

Columbia University, West 116th Street, and 51 East Fifty-fourth Street, New York City.

1884–85, studied chemistry at Lehigh University and Bethlehem Steel Works. 1885-87, studied chemistry, physics, microscopy and bacteria at School of Mines and at College Physicians and Surgeons. Private Assistant to Professor Chandler. 1887–97, Instructor and, later, Demonstrator in Physics and Chemistry at College Physicians and Surgeons. 1897, Adjunct Professor of General Chemistry, Columbia University, with special charge over Laboratory of Industrial Chemistry. Also in general chemical practice with Professor Chandler.

PEUGNET, CHARLES PAUL ERNST, C.E., A.M., . . 1895.

231 West Forty-fifth Street, New York City, N. Y.

October, 1895, to June, 1896, Post-graduate work at Columbia University, Principally in Hydraulic and Electrical Engineering. February to December, 1897, with Metropolitan Street Railway Co. of the city of New York—on Construction Corps in charge of Principal Assistant Engineer. December, 1897, to June, 1898, and from October, 1898, to 1899, with U. S. Nicaragua Canal Commission—on Survey in Nicaragua and subsequent office work at Washington, D. C.

PENNINGTON, JOSEPH POPE, A.M. (Associate), . . 1868.

Madison, N. J.

1881–83, Assistant Engineer E. T. V. & G. R. R. 1883–84, Engineer Tombstone Mill and Mining Co. 1885–93, railroad construction with general contractors. Assistant Secretary, Louisville, St. Louis and Texas Railway. Resigned August, 1893. Previous responsibilities as actuary in connection with life insurance interests.

PERRINE, GEORGE, C.E., ... 1894.

22 William Street, and 820 West End Avenue, New York City, N. Y.

With Chief Engineer Rapid Transit Commission, New York City, 1894–98.

Commissioned Second Lieutenant, First Regiment U. S. V. Engineers, June 7, 1898. Commissioned First Lieutenant, June 28, 1898, and appointed Battalion Quartermaster, later appointed Battalion Adjutant. In Puerto Rico, Aug. 16 to Nov. 17, 1898. Mustered out of service Jan. 25, 1899. Assistant in Columbia University Summer School of Surveying, 1899.

PERKINS, HARRY A., E.E., ... 1889.

Care of Hartford Electric Light Co., and 55 Forest Street, Hartford, Conn.

PERKINS, THOMAS SLADE, PH.B., ... 1888.

Ninth Street and Gowanus Canal, South Brooklyn, and 39 Garden Place, Brooklyn, N. Y.

1889 to date, New York Tartar Company.

PERKINS, SEYMOUR, C.E., ... 1897.

42 West Forty-sixth Street, New York City.

PIERCE, FREDERICK EMERY, C.E., ... 1892.

Dept. of City Works, Room 49, Municipal Building, 194 Joralemon Street, Brooklyn, N. Y.

1892, Employé in Bessemer Mill, Maryland Steel Co., Sparrow's Pt., Maryland. 1893, Draughtsman, New Jersey Steel and Iron Co., Cooper Hewitt & Co., New York City. Trenton, N. J. 1895, P. R. R. Engineer in Corps of Principal Assistant Engineer at Jersey City. 1895-97, Engineer-draughtsman, Wallabout Improvement, Dept. of City Works, Brooklyn.

PIEZ, CHARLES, E.M., ... 1889.

Chief Engineer Dink Belt Engineering Co., Nicetown, and 3124 North Broad Street, Philadelphia, Pa.

1889-91, Draughtsman with the L. B. E. Co. 1891-92, Assistant Chief Engineer L. B. E. Co. Since 1892, Chief Engineer of the L. B. E. Co., and the Dodge Coal Storage Company.

PINKHAM, HERBERT, C.E., ... 1895.

Assistant Superintendent J. J. Astor Estate, Ferncliff Rhinebeck, N. Y., and 176 West Eighty-first Street, New York City.

1895-97, in Engineer's Corps, Principal Assistant Engineer, U. R. Rds. of N. J. Div., Penn. R. R. December, 1897, to date, Assistant Superintendent J. J. Astor estate, Rhinebeck, N. Y.

PISTOR, WILLIAM, E.M., ... 1868.

Architect, 68 Broad Street, New York City.

PITKIN, LUCIUS, A.B., PH.B., ... 1881.

138 Pearl Street, New York City.

1880-85, Chemist to Laurel Hill Chemical Works, of Nicholas Chemical Company, heavy Chemicals, especially sulphuric acid. 1885 to date, Analytical and consulting Chemist, at above address. Specialty in consulting. Manufacturers of acids and heavy chemicals, treatment of pyrites and copper smelting. Analytical work in general but special experience in argentiferous and auriferous copper ores and products. Microscopical and experimental investigations.

POLLEDO, YSIDOSO YGNACIO, E.M., ... 1885.

Apartado 167 and Manzaneda 16 Mantanzas, Cuba.

1885, Assistant Engineer, Survey for Waterworks for City of Santiago de Cuba. 1886-89, Assistant Engineer and Principal Assistant Engineer in charge of track and structures, Cárdenas and Jusuro R. R., Cárdenas. 1889-90, Manager of Santa Barbara Sugar plantations, Baró. 1894-95, General Manager Cárdenas Sugar Refining Co., Cárdenas.

PORTER, H. HOBART, JR., E.M., ... 1886.

Sanderson & Porter, Engineers and Contractors, 31 Nassau Street, New York City, and Lawrence, L. I., N. Y.

1886-87, Fellow in Geology, School of Mines, Columbia University. 1887-88, Surveyor and Assayer Mexican Ore Company, Sierra Mojada, Mexico. 1888-89, Assistant Mining Engineer, Batopilas Mining Company, Batopilas, Mexico. 1889-90, Surveyor and Assayer, Duquesne Mining Co. ; Assistant Superintendent Ray & Poorman mine examinations, same company ; Assistant Superintendent Sierra County, Arizona, same company. 1890-91, Engineer with C. W. Hunt Company. 1891 to date, Westinghouse Electric and Mfg. Co. Member of firm of Sanderson & Porter, Engineers and Contractors Electric Rys. Power Transmission and Lighting.

PORTER, JOHN BONSALL, E.M., PH.D., . . . 1882.

Professor of Mining and Metallurgy, McGill University, Montreal, Canada.

1882-84, Field Work on Economic Geology (coal and iron) of Alabama, Georgia and Tennessee. 1884-88, Instructor and Lecturer on Mining and Mechanical Engineering and Metallurgy in University of Cincinnati and Expert in Metals and Ores for Q. & C. Ry. 1888-92, Engineer Maintenance of Way, C. H. & D. Ry. System. 1893-96, Chief Engineer and Superintendent C. & W. Ry. and Engineer P. & G. Co., Cincinnati, O. 1896, Professor of Mining and Metallurgy, McGill University, Montreal.

POST, ABRAHAM SKIDMORE, C.E., ... 1884.

81 Fulton Street, and 292 Riverside Drive, New York City.

POWELL, FREDERICK, A.B., E.M., ... 1883.

Consulting Engineer, Hammond Manufacturing Co., 69 First Street, Portland, Oregon.

1883-84, Mechanical Draughtsman and Engineer. 1885, Assayer at Duluth, Minn., Examination and Reports on Mineral Deposits in northeastern Minnesota and Canada, Assayer and Manager for Sentinel Gold Mining Co. of Minneapolis and Colorado. 1886-88, Superintendent and Manager in Colorado for Denbigh Mining Co. of New York. 1882-92, Miscellaneous Surveying. 1893, Engineer for Charlotte Mineral and Mining Co., Charlotte, N. C. Examining and Reporting on Mines in North Carolina. June, 1894 to 1896, Mining Engineer, Charlotte, N. C.

POWERS, LEWIS J., JR., E.M., ... 1884.

Connecticut River Paper Company, Holyoke and Springfield, Massachusetts.

1885, Superintendent Vermont Construction Company, St. Albans, Vt. 1886,

Superintendent Standard Pulp Company, Springfield, Mass. 1887-88, Assistant Superintendent Union Paper Manufacturing Company, Holyoke, Mass. 1888 to date, Agent Connecticut River Paper Company, Holyoke, Mass.

PRESTON, WILLIAM EVAN, C.E., ... 1889.

U. S. Engr. Box, foot E. Ninety-second Street, and 980 Trinity Avenue, New York City.

1889 to date, submarine blasting and dredging for U. S. Harbor work, with grapple, divers and centrifugal pumps.

PRINCE, JOHN L., E. E., ... 1894.

Edison Electric Illuminating Co. of New York, 53 Duane Street, New York City, and 868 Flatbush Avenue, Brooklyn, N. Y.

Summer of 1894, Electric Light Station of the Flatbush Gas Co., Flatbush, L. I. Fall of 1894, with the General Electric Co. installing plant for the Bridgeport Traction Co., Bridgeport, Conn. Spring of 1895, in the Department of Public Works, Brooklyn, N. Y. October, 1895, to date, Inspection Department of the Edison Electric Illuminating Co., of N. J.

PROSSER, HERMAN A., E.M., E.E., ... 1896.

B. C. S. & R. Co., Keyser Building, Baltimore, Md.

Summer of 1896, Assistant Engineer Northwestern Mining and Exchange Co., Pa. 1896-97, Electrical Engineering course at Columbia. June, 1897, to February, 1899, Electrician, Baltimore Electric Refining Co., Baltimore, Md. February, 1899, to date, Manager of same.

PROVOST, ANDREW J. JR., C.E., ... 1889.

54 Stewart Building and 401 Washington Avenue, Brooklyn, N. Y.

1889-94, Assistant Engineer in Sewage Construction, Department City Works, Brooklyn, N. Y. 1894-96, Engineer in charge Sewage design, Dept. City Works, Brooklyn, New York. 1896 to date, Secretary Brooklyn Engineers' Club, Consulting Engineer, Columbian Colliery Company. January, 1898, to February 1899, Asst. Engr. Dept. Sewers, New York City. February, 1899, to date, Asst. Engr. Dept. Finance, New York City.

PUTNAM, B. R., B.S., A.M., ... 1893.

Chemist, Montana Ore Purchasing Co., and 316 West Granite St., Butte, Mont.

Received degree of B. S. in Mechanical Engineering from the Rose Polytechnic Institute in 1892, and the degree of A. M., for work in Mining, Metallurgy, etc., from Columbia University in 1893. 1894-96, Assistant Chemist, South Works, Illinois Steel Co. 1896-97, Chemist for the Union Colliery Co., Victoria, B. C. 1897 to date, Chemist and Assayer Montana Ore Purchasing Co., Butte, Mont.

R.

RANDOLPH, JOHN COOPER F., A.B., A.M., E.M., . 1869.

Consulting Mining Engineer, Mill Building, 15 Broad Street, New York City.

RANDOLPH, JAMES FITZ, B.S., E.M., ... 1876.

64 Madison Avenue, Morristown, N. J.

RAYMOND, ROBERT MATTHEW, A.B., E.M., . . . 1889.
The Exploration Co., Johannesburg, S. A. Rep., and 78 Waverly Ave., Newton, Mass.

1880–82, Assistant Assayer, State of Maine Assay Office, Portland, Me. 1882–86, Assayer and Assistant Superintendent, Haile Gold Mine, S. C. 1886–89, School of Mines. 1889-90, Assayer and afterwards Assistant Superintendent Montana Smelting Co., Great Falls, Mont. 1891, Superintendent, The Diamond R. Mining Co., Neihart, Mont. 1894, General Manager Harquahala Gold Mining Co., Harquahala, Ariz. 1896–97, General Manager Harquahala Gold Mining Co., Ltd., Arizona and West Australia. General Manager Brownhill Proprietary Gold Mines, Ltd., and Representative Mines Selection Co., Ltd. 1897–98, General Manager Harquahala Gold Mining Co., Ltd. Consulting Engineer, 1898, with The Exploration Co., West Australia, and 1899, Consulting Engineer same company in South Africa.

RECKHART, DANIEL WILLIAM, E.M. (Life Member), . 1884.
Proprietor Independent Assay Office, Box 88, El Paso, Texas.

RECKHART, GEORGE FREDERICK, C.E., . . . 1892.
Commonwealth Mining and Milling Co., Pearce, Cohie County, Arizona, and 500 W. Thirty-fifth Street, New York City.

Member of "Southwestern Mining Association" (Incorporated). Surveyor and Assayer for Cia Minera La Aventurea, Sabinal, Estado de Chihuahua, Mexico, since September, 1894. From February, 1894, to August, 1894, was on Engineering Staff on South Shore Railroad Co., Ltd., of Nova Scotia, Canada. 1896, Manager, The Furners & Lewis Co., Pachuca, Estado de Hidalgo, Mexico. Since September, 1896, with Commonwealth M. and M. Co., Pearce, Arizona.

REED, SILVANUS ALBERT, A.B., A.M., E.M. (Life Member), ... 1877.
Manager Tariff Association of New York (Fire Underwriters), 32 Nassau Street, New York City.

1878, Secretary to Assistant Commissioner General, Paris Exposition. 1879, Lectured on Chemistry. Reported on Mines in Colorado. 1880-81, Superintendent and part Proprietor, Sampling and Concentration Works in Colorado, and Reported on Mines there and in Idaho and in the South. 1886, Consulting Practice in New York, Patent Expert work and on Dredging in New York Harbor. 1886–91, Superintendent Inspection Department of Fire Insurance Co. (Commonwealth of New York.) 1893, Expert for New Insurance Rating, Mercantile Section of Boston. May, 1893, appointed Manager Western Factory Insurance Association. Special Agent Western Department of Continental Insurance Co. 1894, Manager Tariff Association Fire Underwriters, New York City.

REES, JOHN KROM, PH.D., A.B., A.M., E.M. (Life Member), ... 1875.
Professor of Astronomy and Director of Observatory, Room 610 Fayerweather Hall, Columbia University, and 1 West Seventy-second Street, New York City.

A.M., 1875. E.M., 1875. Assistant in Mathematics, School of Mines, 1873–76. Professor of Mathematics and Astronomy, Washington University, St.

Louis, Mo., 1876–81. Director of the Observatory, Columbia University, from 1881. Instructor in Geodesy and Practical Astronomy, Columbia University, 1881–82. Professor of Astronomy, from 1892, Chairman Board of Editors, SCHOOL OF MINES QUARTERLY, 1883–90. Vice-President New York Mathematical Society, 1891. Chairman of section on Astronomy and Physics of New York Academy of Sciences. 1891–94, Secretary of American Meteorological Society, 1882–97. Fellow of Royal Astronomical Society of London, from 1892. Member of the Astronomische Gesellschaft, from 1893. President of New York Academy of Sciences, 1894–96. Secretary of University Council, 1892–98.

RENAULT, GEORGE, C.E., ... 1883.

122 E. Nineteenth Street, New York City.

RHODES, FRANCIS BELL FORSYTHE, E.M., ... 1874.

National S. & R. Co., South Chicago, Ill., and Quebec, Canada.

May, 1875, to December, 1876, Surveying Corps, Coxe Bros., Drifton, Pa. January, 1877, to May, 1878, Assistant Superintendent, South American Mining Co., Venezuela, November, 1878, to June, 1879, Working at Lead Mine, Canada. October, 1879, to April, 1880, Laborer, Ontario Mill, Park City, Utah. April, 1880, to July, 1881, Assistant Superintendent, Mingo Furnace Co., Utah. August, 1881, to January, 1882, Assistant Superintendent, St. Helena Mine, Sonora, Mexico. January, 1882, to April, 1883, Assistant Superintendent, Tombstone M. and M. Co., Arizona. May, 1883, to December, 1883, Superintendent Ramsham Smelting Furnace, Idaho. January, 1884, to May, 1885, Assistant Superintendent, Mingo Furnace Co., Utah. June, 1885, to December, 1885, Foreman of Blast Furnace Department, Kansas City S. and R. Co. October, 1886, to December, 1888, Superintendent Chicago Works, Chicago and Aurora S. & R. Co. January, 1890, to date, Superintendent National S. and R. Co., South Chicago.

RHODES, ROBERT DUNN, E.M., ... 1879.

Superintendent Philadelphia Smelting & Refining Co., Pueblo, Colo., and Quebec, Canada.

1879–80, Foreman, Germania Smelting Co., Salt Lake City. 1880–82, Night Foreman Ontario Silver Mining Co., Park City, Utah. 1882–83, Superintendent Tombstone, M. and M. Co., Reduction Works, Charlestown. 1883–84, Mill Foreman, St. Helena Gold and Silver Mine, Sonora. 1884–85, Assistant Superintendent, Billings Smelter, New Mexico. 1885–86, Assistant Superintendent Viola M. and S. Co., Idaho. 1887–88, Assistant Superintendent, Anglo-Mexican Mining Co., Yedras, Mexico. 1889–91, General Superintendent, Duquesne M. and R. Co., and Sierra County, Arizona. 1891–92, Engineer Fraser and Chalmers, City of Mexico. 1892, Superintendent. 1896, Arkansas Valley Smelting Works, Leadville, Colo. 1897 to date, Supt. Phila. Smelting and Refining Co., Pueblo, Colo.

RICE, GEORGE SAMUEL, JR., E.M., ... 1887.

936 The Rookery, Chicago, Ill., and 1426 Benson Avenue, Evanston, Ill.

1887, Assistant Field Engineer Colorado & Utah Railway. 1888–89, Assistant Mining Engineer of Colorado Fuel Co. 1890–97, Mining Engineer of Whitebreast Fuel Co. 1897, with Whitebreast Fuel Co., Chicago, Ill.

RICH, JACOB MONROE, E.M., C.E. (Life Member), . 1883.
50 West Thirty-eighth Street, New York City.
Pursuing further studies since graduation.

RICKETTS, PIERRE DE PEYSTER, E.M., PH.D., . . 1871.
Professor of Analytical Chemistry and Assaying, Columbia University School of Mines, and 115 E. Seventy-ninth Street, New York City.
1868, Assistant General Chemistry, Columbia University. 1871-72, Assistant in Mineralogy and Metallurgy, School of Mines. 1872-75, Assistant in Assaying, School of Mines. 1875-86, Instructor in Assaying, School of Mines. 1886 to 1894, Professor of Assaying, School of Mines. Since graduation also engaged in general Metallurgy, Chemical and Mining Engineer work.

RIEDERER, EMIL J., B.S., ... 1897.
Hercules Powder Co., Ashburn, Mo., and 145 W. Ninety-fourth Street, New York City.
Asst. Chem. New Jersey Zinc Works, 1895. With Chas. Cooper & Co., summer 1896. 1898, Assistant in Chemistry, Assay Laboratory, Columbia University, New York City. North American Smelting Co., summer 1899. Chemist of Hercules Powder Co., Ashburn, Missouri (since October, 1899).

RIES, HEINRICH, PH.B., A.M., PH.D., . . . 1892.
Department of Economic Geology, Cornell University, Ithaca, N. Y.
Barnard Fellow in Columbia University. 1897 to 1898, Delegate from Columbia University and New York Acad. of Sci. to 1897, Geological Congress in St. Petersburg, Russia. Summer of 1897, engaged in a study of the important clay deposits of England, Germany, France, Belgium, Austria and Denmark. Fall and winter of 1897, engaged in study of physical properties of clay at the University in Berlin, Germany. Summer of 1891 and 1892, on N. Y. Geol. Surv. October, 1892, to August 1, 1893, Assist. Director, N. Y. Scientific Exhibit, at World's Fair. July 1, 1893, to July 1, 1895, Fellow in Mineralogy, Columbia University. Asst. Geologist, N. Y. Geol. Survey, summer of 1895. Lecturer in New York City Public Schools, 1895-97. Judge of Clays, Cotton States and International Exposition, October, 1895. Clay Specialist, U. S. Geological Survey, 1895 to date. In connection with this work am engaged in a study of the clays of the various States. Summer of 1898 engaged in geological work in Alabama and New York State. 1898, Instructor in Economic Geology, Cornell University, Ithaca, N. Y. Am also engaged in a detailed investigation of the clays of Alabama and New York. Aug., 1899, engaged in examination of Mich. clay deposits. Sept. and Oct., studied mining regions of Pacific coast, contributed articles on geology to International Encyclopedia year-book for 1899-1900.

RITER, LEVI E., Jr., E.M., ... 1899.
Room 305, Atlas Block, and 268 Second Street, Salt Lake City, Utah.

RODENBURG, CHARLES, C.E., ... 1896.
American Diamond Rock Drill Co., 120 Liberty Street, and 428 W. Forty-fourth Street, New York City.

Summer 1896, Assistant at Summer School of Geodesy, Columbia University. December, 1896, with J. L. Greenleaf, C.E., on survey in Adirondacks. From January, 1897, to date, with the American Diamond Rock Drill Co., and also with the Driggs, Seabury Gun and Ammunition Co.

ROESER, FREDERICK, B.S., E.M., ... 1884.
Care of Oceana Consolidated Co., P. O. Box 1542, Johannesburg, S. A. R.

ROGERS, CHARLES E., C.E., ... 1897.
Engineering Department, U. S. A., Key West, Fla.

ROGERS, OSCAR LEGARE, PH.B. (Arch.), . . . 1889.
Head Master St. Matthews Military School, Pocantico, N. Y.
1889–92, in Europe. 1893, Architect. 1894, in Europe.

ROLKER, CHARLES M., E.M. (Life Member), . . 1875.
Leadenhall Building, No. 1 Leadenhall Street, London, E. C., England.
1868–70, at Royal School of Mines, Clausthal, Germany. 1871–72, Working practically in Iron Mines of Hibernia and Mt. Pleasant, N. J., Wisconsin Lead Mines and Iron Mines of Lake Superior. 1872–75, at School of Mines, Columbia College. 1876, Assayer, at Allouez Copper-dressing Works, Lake Superior. 1877, Mining Engineer to the Mariposa Land and Mining Co., Mariposa Co., Cal., (Gold). 1878, Superintendent, Brooklyn Company, Washoe Co., Nevada (Base Metal). 1879, Superintendent Stormont Silver Co., Silver Reef (Silver). 1880–82, General Manager Chrysolite S. Mfg. Co., Leadville, Colo. (Lead Carbonates). Since then to date, in General Consulting Practice as Mining Engineer and Metallurgist, Examining Mines, Mills and Placers in the United States, Old Mexico, Central America, South America and East Indies. Specialty, Precious and Base Metals other than Iron. 1891–92, Consulting Engineer to the British South African Company in its sphere south of Zambesi. 1894, Practicing, Consulting Mining Engineer. 1895–96, Manager Mining and Financial Trust Synd., London. 1899, Consulting Mining Eng.

ROS, JUAN PABLO, B.A. (Havana University), E.M., . 1898.
Vives 48, Cienfuegos, Cuba.

ROSENTHAL, ALBERT, C.E., ... 1892.
221 Coulter Street, Germantown, Philadelphia, Pa.

ROWLAND, CHARLES BRADLEY, C.E., ... 1884.
Continental Iron Works, Greenpoint, Brooklyn, N. Y., and 329 Madison Avenue, New York City.

ROWLAND, GEORGE, C.E., ... 1887.
Assistant Treasurer Continental Iron Works West and Calyer Streets, Brooklyn, N. Y., and 329 Madison Avenue, New York.

RUPP, PHILIP, PH.B., M.D., ... 1884.
Büchens Strasse 29, Heidelberg and Mannheim, B. F., No. 1, Baden, Germany.
1884–87, Student of Medicine, College of Physicians and Surgeons, N. Y.

1887–88, House Physician and House Surgeon, St. Francis Hospital, N. Y. 1888 to 1899, Practicing Physician. 1899, Student in Chemistry, Univ. of Heidelberg.

RUTHERFURD, F. M., E.M., ... 1879.
46 E. Sixty-fourth Street, New York City.

Engineer M. of W. R. and D. R. R. till 1894. 1895 to date, 2d Deputy Superintendent Dept. of Buildings, New York City.

RUTTMANN, FERDINAND, E.M., ... 1880.
Mining Engineer, 45 Broadway and 547 W. 147th Street, New York City.

RYON, AUGUSTUS MEADER, E.M., ... 1886.
97 Main Street, Flushing, N. Y.

1886–87, Assistant Engineer on New London Waterworks. Assistant in Metallurgy, School of Mines, Columbia University. 1887–88, Assistant to F. N. Owen, Civil and Sanitary Engineer, New York City. 1888–91, Professor of Engineering and Mining, School of Mines, College of Montana, Deer Lodge, Mont. 1892–95, President and Professor of Engineering, Montana College of Agricultural and Mechanical Arts, Bozeman, Montana. 1894, Irrigation Engineering for Agricultural Experiment Station. 1895, Professor of Engineering, College of Agricultural and Mechanical Arts, Bozeman, Montana.

S.

SAGE, EDWARD EUGENE, C.E. (Life Member), . . 1877.
United States Assay Office, 30 Wall Street, New York City, and 33 Fairview Avenue, Orange, N. J.

I have been connected with this office since February, 1878, and have consequently no outside experience except electricity, being President of the Essex County Electric Co., of Orange, N. J., and in Analytical Chemistry.

SAUNDERS, GEO. CROSBY, B.S., C.E., . . . 1898.
513 W. 142d Street, New York City.

Assistant in Summer School of Surveying, season 1898.

SCHELL, R. MONTGOMERY, B.S., ... 1895.
156 Fifth Avenue, and Hotel San Remo, 75th Street and Central Park, West, New York City.

1895, with Cady Berg & See, Architects. 1896, with George Keister, Architect. 1897, with Clinton & Russell, Architects. 1898 to date, Architect, 156 Fifth avenue. 1896–98, Instructor in Archt. Drawing, West Side Branch, Y. M. C. A.

SCHERMERHORN, FREDERICK AUGUSTUS, E.M. (Life Member), 1868.
41 Liberty Street and 101 University Place, New York City.

SCHIEFFELIN, WILLIAM JAY, PH.B., PH.D. (Munich), 1887.
Schieffelin & Co., 170 William Street and 35 W. Fifty-seventh Street, New York City.

SCHNEIDER, ALBERT FRANCIS, E.M., C.E. (Life Member), 1876.
77 Pine Street, New York City, and 39 Gordon Street, Perth Amboy, N. J.

1876–77, in Europe visiting Smelting and Dressing Works. 1878, Chemist and Assayer Germania S. and R. Co., Salt Lake City, Utah. 1879, Foreman. Assistant and Superintendent Germania S. and R. Co., Salt Lake City. 1880–83, Superintendent Germania S. and R. Co., Salt Lake City, Utah. 1883–85, Superintendent G. Billing Smelting Works, Socorro, N. M. 1885–87, Superintendent Kansas City S. and R. Co., Argentine, Kansas. 1887, Connected with the Rio Grande S. Co., Socorro, N. M. 1887–93, General Manager St. Louis S. and R. Co., St. Louis, Mo. Superintendent Great National Smelting Co., Monterey, Mexico, 1895. At present, Cons. Metallurgist and Mining Engineer, New York City.

SCHROEDER, J. LANGDON, C.E., ... 1889.

Member of the firm of Praish & Schroeder, Architects, 3 W. Twenty-ninth Street, and 50 W. Eleventh Street, New York City.

July, 1890, to January, 1894, with Renwick, Aspenwall & Renwick, New York City, Architectural Draughtsmen.

SCHUMANN, CHARLES HENRY, C.E., ... 1888.

Small & Schumann, 265 Broadway and 21 E. Ninety-ninth Street, New York City.

1888, to May, 1890, Assistant Engineer Chesapeake and Ohio Railway Co., Cincinnati, charge of Real Estate, Right of Way and Track and Construction Work. May to August, 1890, Assistant Engineer to H. Alber, C.E., Birmingham, Ala., General Engineering. August, 1889, to March, 1891, Assistant Engineer, Chesapeake and Ohio Railway Co., charge of subdivision of Town of West Clifton Forge, Va., and Right of Way on line of road. 1892-93, Assistant Engineer Long Island R. R., and Engineer for Ferris & Richards, Contractors for Railroads and Waterworks, Fayetteville, N. C. 1893-94, with James R. Croes, C.E., Waterworks Supply and Sewage. 1894, Private practice as Small & Schumann, Architects and Civil Engineers.

SCUDDER, HEWLETT J., E.E., M.A., ... 1899.

21 East 22d Street, New York City.

SEARLE, CHARLES D., C.E., ... 1896.

32 W. 126th Street, New York City.

SELDNER, RUDOLPH, PH.B., B.S., ... 1894.

217 Jefferson Avenue, Brooklyn, N. Y.

Instructor in Science, Adelphi Academy, 1894-97. Chemist Orangeburgh Chemical Works, 1897-98.

SELF, E. D., E.M., M.E., ... 1894.

Manager San Carlos Copper Co., San José, Tamaulipas, Mexico, and South Orange, N. J.

Received degree of Mechanical Engineer at the Stevens Institute of Technology in 1886. Engaged in Engineering and Construction work. Designing and purchasing machinery for large mills in Australia and Mexico. Reports on transmission of power project for mining plant in Mexico. Examination of Mines in South America. Superintendent of mine in Guyana, South America. Received

degree of Engineer of Mines from Columbia College in 1894. Assistant in Mining at Lake Superior for class in practical mining. Superintendent and Manager of the Sonora Copper Co., Sonora, Mexico. Received patent for System of ore concentration. Consulting Mechanical and Mining Engineer on deep level work, Report as Consulting Engineer on Mineral Land Grant of 10,000,000 acres of Cassiar Central Railway Co., B. C., and General Manager of Company's prospecting and business operations in Cassiar district, B. C.

SESSINGHAUS, GUSTAVUS, E.M., M.S. (Univ. Wis., 1899), 1898.
Flat River, St. Francis Co., Mo., and 2401 North Twelfth Street, St. Louis, Mo.

Field Assistant U. S. Geol. Survey, Summer of 1898. Since Summer of 1899, Mining Engineer.

SEWARD, JOHN, E.M., ... 1895.
417 Main Street, Orange, N. J.

SHARE, WILLIAM WALDEMAR, PH.B., PH.D., . . 1881.
Adelphi College, and 331 McDonough Street, Brooklyn, N. Y.

1881, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1881–88, Assistant Physics, Columbia College. 1888, Consulting Electrician, Department of Public Parks, Brooklyn, N. Y. 1889 to date, Professor of Chemistry, Adelphi Academy, Brooklyn, N. Y.

SHATTUCK, L. R., B.S., C.E., ... 1895.
Care of John Monks & Son, 130 Water Street, New York City, and 184 Eighth Avenue, Brooklyn, N. Y.

1895, Draughting and Field work with the Ramapo Water Co. 1896–97, Engineer Inspector in the Department of Public Works, of New York City. 1898 to date, Assistant Superintendent of Construction and Sinking of Caissons for New Cincinnati Waterworks at California, Ohio.

SHERMAN, FRANK DEMPSTER, PH.B., ... 1884.
Adjunct Professor of Architecture, 603 Havemeyer Hall, Columbia University, New York City, 312 South Broadway, Yonkers, N. Y.

SHERMAN, G. F., C.E., ... 1894.
Grass Valley, Nevada Co., Calif.

SHERMAN, HENRY C., A.M., PH.D., ... 1897.
Wesleyan University, and Drawer 74 A, Middletown, Conn.

Summer of 1893, Assistant Dairy Chemist, World's Fair, Chicago. 1893-94, Assistant in Chemistry, Maryland Agricultural College. 1894–95, First Assistant Chemist. 1895–97, Fellow in Chemistry, Columbia University. 1897–98, Assistant in Chemistry, Columbia University. 1898 to date, Assistant in Nutrition Investigations, United States Department of Agriculture.

SHRIVER, HENRY TOWER, PH.B., ... 1888.
T. Shriver & Co., 633 E. Fifty-sixth Street, and 686 Park Avenue, New York City.

In Iron Foundry and Works, as above, since Graduation.

SIMONDS, FRANCIS MAY, E.M., PH.D., . . . 1887.

Member of Firm Simonds & Wainwright, 159 Front St., New York City, and 127 Maple Ave., Flushing, L. I., N. Y.

1887–89, Working for Degrees of Ph.D., and Assistant in Assaying at School of Mines. 1889–92, Assistant in Assaying at School of Mines and Chemist to Messrs. Ricketts & Banks. 1892–93, Lecturer in Assaying and Chemist as above. 1893–94, with Sterling Supply Co., Manufacturing Street Railway Supplies. 1894–95. Opened a laboratory at No. 30 Platt St., N. Y., for experimental work in the treatment of Ores and Chemical Products. 1895. Associated with me in partnership, Mr. T. H. Wainwright, Class 1882, forming firm of, Simonds & Wainwright, Chemical and Mining Engineers and Analysts.

SINGER, GEORGE, JR., E.M., ... 1880.

111 Fourth Avenue, Pittsburg, Pa.

SINGER, GEORGE HARTON, E.M., ... 1880.

Singer, Nimick & Co., Incorporated, Pittsburg, Pa.

SKINNER, ELMER, C. E., ... 1891.

227 Cumberland Street, Brooklyn, N. Y.

SLACK, CHARLES GODDARD, E.M., ... 1884.

328 Fourth Street, Marietta, Ohio.

SLADE, RICHMOND EDWARD, PH.B., ... 1887.

Supt. Water Co., Tampa, Fla.

1887, Assistant Superintendent United Gas Improvement Co., Yonkers, N. Y., Plants. 1888, Superintendent Gas Department, Asheville (N. C.) Light and Power Co. 1888, Superintendent Gas and Electric Plants, Citizen's Gas Light Co., Jackson, Tenn. December, 1889, to date, Secretary, Superintendent and Trustee Citizens' Gas and Electric Co., White Plains, N. Y. 1896, Secretary and Superintendent and Trustee Citizens' Gas and Electric Co., Secretary and Director New York, Elmford and White Plains Ry. Co., and Manager Consolidated Gas and Electric Light Co., of Westchester County, Port Chester, N. Y. 1899, Supt. Tampa, Fla., Water Co.

SLAVEN, R. E., ... 1899.

119 West 72d Street, New York City, N. Y.

SMITH, AUGUSTUS, A.B., C.E., ... 1889.

39 Cortlandt Street, New York City.

Summer of 1896, Land Surveying (in charge of party). July to November, 1889, Draughtsman, Link Belt Engineer Co., Nicetown, Phila. November, 1889, to 1891, Chief Draughtsman New York Office Link Belt Engineering Co. 1891–92, out of professional work. 1892, Salesman and Engineer as above. 1893 to date, private practice as Engineer and Contractor.

SMITH, FRANK MARSHALL, E.M., ... 1889.

Am. Smelting and Refining Co., Smelter P. O., Great Falls, Mont.

1889–90, on the United States Geological Survey, engaged in hydrographic work on the Irrigation Survey and triangulation of the Topographic Survey in Idaho and Oregon. 1891, Assayer Colorado Smelting Co., Pueblo, Colo. October, 1892,

to 1893, Assistant Superintendent. 1893 to date, Supt. United Smelting and Refining Co., Smelter, Mont. January 1, 1898, appointed Manager United Smelting & Refining Co., Great Falls Works. 1899, appointed Manager Great Falls Plants Am. Smelting and Refining Co.

SMITH, FRANCIS PITT, PH.B., ... 1888.

College of Physicians and Surgeons, Fifty-ninth Street and Tenth Avenue, New York City, and 77 Woodland Avenue, New Rochelle, N. Y.

Analytical Chemist in Leather trade, 1888–89. Superintendent Chemical Works, Wm. H. Swift & Co., East Boston, Mass., 1889-90. Consulting Chemist, Deming & Logan, 58 William Street, 1890. Assistant Chemist, New York City Health Department, 42 Bleaker Street, 1890-91. Consolidated Gas Company, New York City, 1891–92. Chemist United States Navy Department, Bureau of Supplies and Accounts, and Editor Anthony's Photographic Bulletin, 1892–95. Harrison Brothers & Co., Philadelphia, Pa., 1885–96. Superintendent Eidoloscope Co., 1896-97. Tutor in General Chemistry, Columbia University, 1897.

SMITH, LENOX, A.B., A.M., E.M. (Life Member), . 1868.

47 Cedar Street, New York City.

SMITH, WILSON, FITCH, C.E., ... 1894.

35 William Street; *for mail*, 36 W. Thirty-sixth Street, New York City.

June to Oct., 1894, Assistant Instructor Summer School of Surveying, School of Mines, Columbia College. Oct., 1894, to Oct., 1896, Engineering Department, New York Central & Hudson River R. R., as Rodman, later Assistant Engineer. Oct., 1896, to Jan., 1897, with R. W. Hildreth & Co. Jan., 1897 to June, 1898, Assistant to William Barclay Parsons, Chief Engineer New York Rapid Transit Commission. June to August, 1898, Assistant Engineer Riverside Drive Viaduct, New York. Nov., 1898, to date, Assistant to George S. Morison, Civil Engineer.

SMITH, WILLIAM ALLEN, E.M., ... 1898.

Care of El Paso Smelting Works, El Paso, Texas.

SMYTH, CHARLES HENRY, JR., PH.B., PH.D., . . 1888.

Professor of Geology and Mineralogy, Hamilton College, Clinton, N. Y.

1888–89, Chemist Franklin Iron Mfg. Co. 1889-90, Geological Field Work in New York, Alabama, Georgia and Tennessee. June, 1890, received Degree of Doctor of Philosophy from Columbia University. 1889-91, studied Petrography and Mineralogy with Prof. Rosenbusch at the University of Heidelberg. 1891, appointed Professor of Geology and Mineralogy in Hamilton College. Asst. on N. Y. Geol. Survey, 1893-95. 1897, appointed by the State Geologist to take charge of the Mapping of the Western half of the Adirondack Region. Interested chiefly in Petrographic and Chemical Geology and in Mineralogy.

SNOOK, THOMAS EDWARD, E.M., ... 1884.

Architect, 261 Broadway, New York City.

1884–87, Superintendent Construction for John B. Snook, Architect. 1887 to date, Members of the firm of and Chief Engineer for John B. Snook & Son, Architects.

SOUTHARD, GEORGE CARROLL, C.E., ... 1892.
111 Montague Street, Brooklyn, N. Y.
1892-93, Equity Gas Works Construction Co. 1893-94, Heine Safety Boiler Co. 1894-95, Hecker-Jones-Jewell Milling Co. 1895-97, Southern Pine Co. of Georgia. 1897, Department Public Works, New York City. 1898 to date, New Jersey Zinc Co.

SPOONER, ALLEN NEWHALL, C.E., ... 1886.
Department of Docks and Ferries, Pier A, North River, New York City, and 186 Carteret Avenue, Jersey City, N. J.
July, 1886, to August, 1887, Rodman and Draughtsman, Penn. R. R., Jersey City, August, 1887, to May, 1890, Hydrographer Department Docks, New York City. May, 1890, to 1891, to present time, Assistant Engineer Department Docks, New York City. Specialty, Railroad Engineering, River, Submarine and Harbor Engineering.

STANTON, FRANK MCMILLAN, E.M., ... 1887.
Superintendent Atlantic Mine, Houghton Co., Mich.
1887-88, Superintendent *pro tem.* Central Mine, Mich. 1888-89, Engineer Atlantic Mine, Mich. 1888 to date, Superintendent Atlantic Mine, Mich.

STAREK, EMIL, LL.B., LL.M., E.M., . . . 1895.
Councilor at Law, 907 Chemical Building, St. Louis, Mo.
1885-87, Assistant in United States Geological Survey. 1887-92, Assistant Examiner United States Patent Office, Washington, D. C.

STAUNTON, WILLIAM FIELD, E.M., ... 1882.
Superintendent of the Congress Gold Co., Congress, Ariz.
1882, Assayer and Assistant Superintendent Vermont Copper Co., Ely, Vt. 1882, Assayer and Accountant Dunn Mt. Gold Mine, Salisbury, N. C. 1883, Assayer Ledoux & Ricketts, N. Y. 1883, Constructing Engineer, C. M. and R. Co., N. Y. 1883, Assistant to Manager of Mills and Smelting of T. M. and M. Co., Tombstone, Arizona. 1884, Consulting Engineer, N. Y. 1884, Mining Engineer for T. M. & M. Co., Tombstone, Arizona. 1890 to date, Superintendent Tombstone Mill and Milling Co., Tombstone, Ariz., and 1894, Superintendent Congress Gold Co., Congress, Ariz. Specialty, Gold and Silver Mining and Metallurgy.

STEARNS, THOMAS BEALE, E.M., ... 1881.
1720 California Street, Denver, Col.

STEWART, JOHN HENRY, C.E. . . . . 1895.
123 W. Eleventh Street, New York City.

STONE, GEORGE CAMERON, PH.B., PH.D., . . . 1879.
The New Jersey Zinc Company, Newark, N. J.
1879, Chemist, Booth and Edgar Sugar Refinery. 1879-82, Chemist with Potter & Riggs, St. Louis, Mo. 1882-91, with New Jersey Zinc and Iron Company, Newark, N. J., first as Chemist, since 1884 as Superintendent Blast-Furnaces. May, 1894, to date, Superintendent of Company.

STRUTHERS, JOSEPH, PH.B., PH.D. (1895), . . 1885.

Assistant Editor of the Mineral Industry, Scientific Publishing Co., 253 Broadway, New York City, and Honorary Lecturer in Metallurgy, Columbia University, Home address 624 East 136th Street, New York City.

1885-88, Fellow in Mineralogy. 1888-1900, Tutor in Metallurgy. 1900, Honorary Lecturer in Metallurgy, Columbia University, School of Mines. For the greater part of the school years 1893, '94, '96 and '97, was in charge of all the lectures in the Department of Metallurgy in place of Dr. Egleston, who was absent on sick leave, in 1897 resigned. 1897-1900, In charge of lectures on General Metallurgy and the Metallurgy of Lead, Silver, Gold, Zinc, etc.

My summer work has been as follows: 1886-94, partly devoted to Metallurgical trips in the West and South, and in Europe. 1895, special work in Pyrometry and Calorimetry. 1896, Organized and had charge of the first Summer School in Practical Metallurgy at Butte, Montana. 1897, In charge of the Summer School in Practical Metallurgy at Chicago, Ill., and Pittsburg, Pa. 1898-99, Assisted at Summer Schools held in Pennsylvania and Maryland. Contributor and on Editorial Staff of the SCHOOL OF MINES QUARTERLY from 1892 to date. Business Manager of the SCHOOL OF MINES QUARTERLY, 1892, '93, '95 to 1900. 1900. Resigned position of Tutor in Metallurgy to accept that of Assistant Editor to the Mineral Industry.

STUART, WILLIAM HENRY, C.E., ... 1886.

36 W. Seventieth Street, New York City.

1886, on Railway Surveys in Minnesota and Wisconsin with C. B. & N. R. R. Co. 1887-89, Fellow in Engineering and Assistant in Summer School of Surveying, School of Mines, Columbia University. 1889-90, making surveys and superintending construction at the Hudson River State Hospital, Poughkeepsie, N. Y. 1890, on Surveys in the West Indies. 1893, in general practice.

SUTER, GEORGE AUGUSTUS, L.M., ... 1883.

G. A. Suter & Co. Engineers and Contractors, 112-114 Wooster Street, New York City, and New Rochelle, N. Y.

1884-92, Engineer, Baker, Smith & Co. 1892-97, with G. A. Suter & Co.

SUTRO, HARRY H., B.S., ... 1898.

60 W. Forty-ninth Street, New York City.

SWAIN, ALFRED ERNEST, E.M., ... 1881.

Kansas City S. & R Co. Cons., Sierra Mojada, Mexico.

1881-84, railroad work in Mexico. 1885-88, City Engineer's Department, Kansas City, Mo., in charge of sewer work. 1889-91, mining work in Mexico. 1891, Superintendent San Buenaventura Mining Company, Santa Lucia, Sinaloa, Mexico, via Mazatlan and Panama. 1891-93, Superintendent of Trinidad Mining Company. 1899, Superintendent Trinidad Mining Co., Copala, Mexico.

T.

TATLOCK, JAMES LLOYD, C.E.. . . . . 1898.

Pelham Manor, New York City.

Employed on construction of sewer outlet from village of New Rochelle. Work

includes pile driving, dredging, drilling and blasting rock bottom and driving of a tunnel four hundred feet long.

TAYLOR, JOSEPH B., E.M., ... 1888.

56 and 58 Pine Street, New York City, and 404 Seneca Street, Brooklyn, N. Y.

1888-90, Practical Shop Work. 1890-94, Draughtsman and Assistant Superintendent Columbian Iron Works, Brooklyn, N. Y. 1894 to date, General Practice, Mechanical Engineering.

TERHUNE, RICHARD HENRY, E.M., ... 1870.

P. O. Box 562, Salt Lake City, Utah.

1870, Assistant to late J. W. Foster, geology of coal fields, Indiana. 1871, Griswold Steel Works, draughting, bowling steel, etc. 1872-77, Joilet Steel Company, draughting, inspecting steel rails and exploration of Callaway County, Missouri for coal and iron. 1877-80, Superintendent and Assistant Superintendent Smelting Works, Utah. 1880-93, General Superintendent Hanauer Smelting Works, Utah. Specialty, construction and operation of lead smelting works. Resigned above position September, 1893. 1894, Examining and Reporting on Mines and Works. October, 1896, reëlected to the position of Chief Engineer and General Superintendent of the Hanauer Smelting Works, Utah. Retired from above position April, 1899. Now engaged in private practice as mining expert and consulting Metallurgist.

THACHER, ARTHUR, C.E., E.M., ... 1877.

President and General Manager Central Lead Company, 420 Roe Building and 4304 Washington Avenue, St. Louis, Mo.

1877-78, with Progreso Mining Company, Trimfo, Lower California, Mexico. 1879-83, Southern Arizona and Northern Mexico Mining and Milling. 1883-87, office in New York. Examining and reporting on mining and mills. 1887 to date, with Professor W. B. Potter, at St. Louis, Sampling and Testing Works and Washington University. Lecturing on Metallurgy. Testing ores, etc. Examining and reporting on mines and mills. Superintendent Central Lead Co. 1896 to date, Prest. Renault Lead Co., and Prest. Lead Belt Ry.

THOMAS, FREDERICK MAYHEW, E.M., . . . 1885.

Box 204, Skaneatilis, N. Y.

Leveller (Instrument man, etc.) on New York Canals, from September, 1887, to November, 1889 (position resigned). Transitman and leveller on preliminary railroad survey in Schoharie County in spring of 1890. Transitman and leveller on Syracuse Waterworks during the winter of 1890-91. Assistant Engineer and later Principal Assistant to City Engineer, Syracuse, N. Y., from August, 1891, to July 1, 1896. Position resigned on account of ill health. Out of active professional work on account of health until the fall of 1898.

THYNG, WILLIAM S., E.M., ... 1896.

Professor of Mining, Washington Agricultural College and School of Science, Pullman, Wash.

1896-97, Editorial Staff of Railroad Gazette of New York. 1897-98, Assistant Engineer of the Tubular Dispatch Company, New York City. 1898, Instructor in Metallurgy, in the Pennsylvania State College. 1898-99, Assistant in the

Mining Department, School of Mines, Columbia University. Summer of 1899, Assistant in Summer School of Practical Mining, Columbia University. July, 1899, to date, Assistant Professor of Mining, Washington Agricultural College and School of Science.

TIBBALS, GEORGE ATWATER, C.E., ... 1883.

The Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.

TIBBALS, SAMUEL GAYLORD, C.E., ... 1884.

The Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.

1884 to date, as above.

TITCOMB, HAROLD A., A.B., E.M., ... 1898.

Box 221, Joplin, Mo., and Care of S. V. White, Columbia Heights, Brooklyn, N. Y.

Nov., 1898, to May, 1899, visiting California and Colorado mines. May, 1899, to date, professional examinations of Missouri lead and zinc properties.

TITUS, WARREN HARRIOTT, E.M., ... 1885.

Sanitary Engineer, Lincoln Building, 1 Union Square, New York City, N. Y., and Whitestone, N. Y.

1885-86, Post-graduate Course in Civil Engineering School of Mines and traveling in Europe. From 1886 to 1892 in the Board of Health employed as follows: From October, 1886-87, Assistant Sanitary Engineer and Inspector of Plumbing. From 1887-88, Assistant Sanitary Engineer and Special Inspector of Plumbing, Drainage, Light and Ventilation. From 1888 to November, 1890, Assistant Sanitary Engineer and Special Inspector and Examiner of Plans for Plumbing, Drainage, Light and Ventilation. From November, 1890, to June, 1892, Assistant Chief Inspector of the Division of Plumbing, Drainage, Light and Ventilation. From December, 1891, to June, 1892, Acting Chief Inspector in charge of Division of Plumbing, Drainage, Light and Ventilation. From June, 1892, to October, 1895, Examiner of Plans for Plumbing, Drainage, Light and Ventilation in the Department of Buildings of New York City. 1885, Practicing as Sanitary Engineer, New York City. Specialties, Plans, Specifications and Superintendence of Water Supply and Sewage Disposal Plants for Country Residences and Institutions; Plumbing, Plans and Specifications for Large City Buildings, including Fire Service.

TONNELE, THEODORE, PH.B., ... 1880.

Care of Wm. Dewees Wood Co., McKeesport, Allegheny Co., Pa.

In charge of Refining and Steel Departments of the William Dewees Wood Company.

TOWER, FREDERIC WEATHERWAX, E.M., ... 1887.

Assistant Examiner, Room 223 Patent Office, Washington, D. C.

TOWNSEND, F., E.E., ... 1896.

Tutor in Electrical Engineering, Columbia University, and 173 Fifth Avenue, New York City,

TRAPHAGEN, FRANK WEISS, PH.B., PH.D., . . 1882.

Chemist in charge of Chemical Laboratory, Montana College of Agriculture, Bozeman, Mont.

1883-84, Chemist for Williams, Clark & Co., Fertilizers. 1884-87, Instructor in Chemistry and Physics, Staunton Military Academy, Staunton, Va. 1887, Professor of General, Analytical and Applied Chemistry and Assaying in the College of Montana and Montana School of Mines. 1884-87, Analytical and Consulting Chemist, Staunton, Va. 1887, Principal work, fertilizer, iron and steel, clays, etc. Analytical and Consulting Chemist and Assayer, Deer Lodge, Mont. Assaying, miscellaneous analysis and legal work. 1890, Assayer for the Champion Consolidated Mining Company, Deer Lodge, Mont. 1892-93, in charge Montana Mining Exhibit at Columbian Exhibition. 1893, Professor Chemistry, Montana College of Agriculture and Mechanical Arts. 1895, Chemist Montana Agricultural Experiment Station.

TRASK, GEORGE FRANCIS DONNELL, E.M., . . 1887.

Secretary and Treasurer, The Central Contracting Co., 99 Cedar Street, New York City, and 12 Tompkins Avenue, New Brighton, S. I., N. Y.

1888-90, Apprentice and Machinist, L. & N. Railroad. 1890-91, Draughtsman, L. & N. Railroad, Louisville. In 1895-96, doing business as George F. D. Trask, Electric Railway Contractor ; in 1896, as member of Trask, Burns & Co., Electric Railway Contractors. 1898, Secretary and Treasurer, The Central Contracting Co.

TUSKA, GUSTAVE ROBITSCHER, B.S., M.S., C.E., . 1891.

62 William Street, and 103 W. Fifty-eighth Street, New York City.

1891-92, Civil and Mechanical Engineer Link-Belt Engineering Co., Philadelphia. 1892-93, Bridge Engineer, Long Island Railroad. Assistant Engineer C. N. Y. and W. R. R., in charge of Stony Brook viaduct, 1893. Consulting Engineer Port-au-Prince Ry., Cuba, 1893 to date. Resident Engineer, Knoxville, Cumberland Gap and Louisville R. R. Co., in charge of Construction of Louisville Viaduct, 1893. Assistant to Professor of Civil Engineering, Columbia College, 1893. Tutor in Civil Engineering, School of Mines, 1894-95. 1896 to date, Chief Engineer Panama Railroad Co., and in general practice as Consulting Engineer.

TUTTLE, EDGAR GRANGER, E.M., ... 1881.

Tecoma, Elk Co., Nevada.

1881, Assistant Engineer Tilly Foster Iron Mine, Brewster, N. Y. 1881-82, Division Engineer, Wheeling and Lake Erie R. R., Toledo, O. 1882-83, Assayer and Mining Engineer, Silver City, New Mexico. 1883-85, Division and Office Engineer, Arizona and Mew Mexico Railroad, Lordsbury, Arizona. 1885, Constructing Engineer at Mines, Arizona Copper Co., Clifton, Arizona. 1885-89, Mining Engineer, Cambria Iron Co., Johnstown, Pa. 1889-94, Superintendent Alamo Coal Co., and Coahuila Coal Co., San Felipe, Coahuila, Mexico. Box 109, Eagle Pass, Texas. 1894, Examinations in Deep River Coal Field for Egypt Coal Co., North Carolina. 1894, Examination in Pocahontas Field, West Virginia. 1895, Writing "Surface Arrangements of Bituminous Mines," for Correspondence

School of Mines, Scranton, Pa. 1895, Expert Examinations of Property and Operations of Columbus and Hocking Coal and Iron Co., Columbus, Ohio, for Bondholders' Committee.

TYLER, WALTER LINCOLN, C.E., ... 1887.
116–120 Front Street, and 1314 Pacific Street, Brooklyn, N. Y.
1887, Levelman and Transitman on the Roanoke and Southern Railroad, Va. 1888, with J. A. Latham, C.E., Providence, R. I. 1888–89, with F. N. Owen, E.M., Sanitary Engineer, New York City. 1889 to the present time, with the A. B. See Manufacturing Co., 116-120 Front Street, Brooklyn.

V.

VAIL, LEWIS H., E.E., ... 1894.
Met. St. Ry. Co. 50th Street and 6th Avenue and 64 West 55th Street, New York City, also Locust Valley, L. I., N. Y.

VANDERBILT, WILLIAM D., C.E., ... 1894.
Western Electric Co., 57 Bethune Street, New York, and 39 Monroe Place, Brooklyn, N. Y.

VANDERPOEL, FRANKLIN, E.M., PH.D., . . . 1875.
Chemist, The Celluloid Co., 295 Ferry Street, Newark, N. J., and 153 Center Street, Orange, N. J.
1875-78, Salesman with E. B. Benjamin. 1878 to date, as above.

VAN ARSDALE, WILLIAM HENRY, A.B., A.M., E.M., . 1868.
Aurora, Ills.

VAN CORTLANDT, EDWARD NEWENHAM, E.M., . . 1885.
Gorontalo, Island Celebes, Care of Netherland Trading Society, Dutch East Indies.

VAN DEVENTER, CHRISTOPHER, E.E., ... 1897.
300 Temple Avenue, Knoxville, Tenn.

VAN GELDER, ARTHUR P., PH.B., ... 1896.
Care of Atlantic Dynamite Co., Rustic, N. J.
1896–97, Assistant Chemist of the Hygeia Sparkling Distilled Water Co., of New York. 1896–97, Assistant in Chemistry in the College of Physicians and Surgeons. 1897–98, Tutor in General Chemistry, Columbia University. 1898–99, Chemist Reparino Chemical Co.

VAN DYCK, WM. VAN B., B.S., E.E., ... 1897.
Instructor in Electricity, Rutgers College, and 84 College Avenue, New Brunswick, N. J.
1897–99, American Luxfor Prism Co.

VAN SINDEREN, HOWARD, PH.B., ... 1881.
Attorney and Counselor-at-Law, 35 Wall Street, and 14 West Sixteenth Street, New York City.

VAN VOLKENBURGH, EDWARD, JR., C.E., . . . 1888.
Morgan & Bartlet, 41 Wall Street, New York City.

VONDY, RUDOLPH HARRISON, E.M., ... 1882.
44 Kensington Avenue, Jersey City, N. J.

1882–83, Assistant Engineer, Tilly Foster Iron Mine. 1885–92, Chemist Phœnix Iron Works, Phœnixville, Pa. 1892, Superintendent Plenty Hort'l and Skylight Works.

VON NARDROFF, ERNEST ROBERT, E.M., . . . 1886.
Instructor, Erasmus Hall High School, Flatbush, and 360 Tompkins Avenue, Brooklyn, N. Y.

VREDENBURGH, WATSON, JR., C.E., ... 1898.
R. W. Hildreth & Co., 32 Broadway, and 225 W. 139th Street, New York City.

Previous to entering college served 4 years in office of R. W. Hildreth & Co. Summers during College course as Inspector for R. W. Hildreth & Co. Since graduation, Bridge Inspector, representing R. W. Hildreth & Co., New York City, and The Osborne Co., Civil Engineers, Cleveland, Ohio.

VULTÉ, HERMAN T., PH.B., PH.D., ... 1881.
Instructor in Chemistry, College of Physicians and Surgeons, 437 W. Fifty-ninth Street, New York City, and 33 Park Avenue, New Rochelle, N. Y.

1881–82, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1883–92, Assistant Instructor in Analytical Chemistry. School of Mines. Tutor in Chemistry, 1892–97, Instructor in Chemistry. Professor of Chemistry, Barnard College, 1892 to date. Engaged in investigating new Analytical Methods. Specialty, Commercial Organic Analysis Expert in Oils, Fats, Soap, etc.

W.

WAINWRIGHT, JOHN HOWARD, PH.B., . . . 1882.
Member of firm Simmonds & Wainwright, 159 Front Street, and 22 W. Forty-sixth Street, New York City, N. Y.

1882, Chemist, Sanderson Bros. Steel Co., Syracuse, N. Y. 1883–98, Chemist U. S. Gov't Laboratory, Appraiser's Office, N. Y. Resigned government office April, 1898, and now associated in partnership with F. M. Simonds, class 1887, forming firm of Simonds & Wainwright, Chemical and Mining Engineers and Analysts.

WALKER, ARTHUR LUCIEN, E.M., ... 1883.
Manager Guggenheimer Smelting Co., Perth Amboy and Elizabeth, N. J.

1883–84, Chemist and Assayer, Old Dominion Copper Co., Globe, Arizona. 1885, Assistant Superintendent in same Company. 1886, engaged in connection with Iron Metallurgy in New York City. 1887, Mechanical Engineer for Silver King Mining Co., Silver King, Arizona. 1888–93, Superintendent Old Dominion Copper Co., Globe, Arizona. Also report on all classes of Mining and Metallurgical Property in Arizona. 1893–95, Consulting Engineer Old Dominion Copper

Co. 1893–97, Manager Baltimore Electrolytic Refining Co., Baltimore, Md. 1898, Manager Baltimore Copper Co. 1899, Manager Guggenheimer's Smelting Co.

WALKER, H. V., PH.B. . . . . 1874.
38–40 Clinton Street, Brooklyn, N. Y.

WALLER, ELWYN, A.B., A.M., E.M., PH.D., . . 1870.
7 Franklin Place, Morristown, N. J.

1871, Assistant Analytical Chemistry, School of Mines. 1877, Instructor Analytical Chemistry, School of Mines. 1885–93, Professor of Analytical Chemistry, School of Mines. 1872–85, Inspector and Chemist, N. Y. Health Department.

WAMPOLD, LEO, PH.B., ... 1888.
204 Monroe Street, Chicago, Ill.

WARD, DELANCY WALTON, PH.B., ... 1888.
Whitestone, N. Y.

WARNER, JOSEPH LOWERY, E.M., ... 1887.
P. O. Box 621, Spokane, Wash.

August, 1887, to August, 1888, Omaha and Great Smelter, Denver, Assistant Assayer. August, 1888, to July, 1889, Examination of and Reports on Mines in Cœur d'Alene, Idaho, and in O'Kanagrn Mining District, Washington. Manager La Bellevue Mine, same district. July, 1889, to January, 1890, Assistant Superintendent and Amalgamator, Golden Monarch Mine, Oregon. January, 1890–92, Examination and Reports on Mines in Western Washington. Manager, Culver Mining Co., and V. P. Vermilion Iron Co. 1892, Examinations in Cascade Range. 1893, Examinations of Iron Deposits, Island of Texado, British Columbia.

WATSON, FREDERICK MORGAN, E.M., . . . 1885.
Joint Mngr. The Cons. Gold Fields of So. Africa, Ltd. P. O. Box 67, Johannesburg, S. A. R.

1885, Assayer and Surveyor, La Maria Mining Co., Mexico. 1888–89, Engineer, Mill Superintendent Sembrerete Mining Co., Mexico. Concentration and Lixiviation. 1890, Engineer for Peruvian Exploration Syndicate, Ltd., Peru. 1891 to date, Examining Engineer, for Frenchville Bros. Special Experience in Roasting Rebellious Ores. Lixiviation by Russel Process and Superintendent as above. Superintendent "Compania Andes" till 1896. 1896, Engineer Consolidated Gold Fields of South Africa. 1896–99, Superintendent, Simmer & Jack Gold Mining Co., Germiston, Johannesburg, S. A.

WATSON, ROLLA BARNUM, E.M., ... 1891.
Care Mexican Copper Co., Ramos, San Luis Potosi, Mexico.

Assayer, Candemena, Mexico, 1891. 1892, Erecting Power Plant for Electric Street R. R., Atlanta, Ga. September, 1893, with Dewey-Walter Refining Co., Park City, Utah. December, 1893, Superintendent Dewey-Walter Refining Co. May, 1895, Foreman Marsac Leacher. 1896 to 1898, Asst. Mgr. Russell Process Co. May, 1898, Supt. Marsac Mill for Ontario Silver Mining Co. December, 1898, to date, Manager Mexican Copper Co., Ramos, San Luis Potosi, Mexico.

WEED, WALTER HARVEY, E.M., ... 1883.

U. S. Geological Survey, Washington, D. C., and care S. R. Weed, South Norwalk, Conn.

1883 to date, Geologist on the United States Geological Survey.

WEEKS, WILLIAM HOLDEN, PH.B., ... 1889.

789 Madison Avenue, New York City.

1889-90, Assistant Chemist, New York Chemical Manufacturing Company. April, 1890, to date, Assistant Chemist Health Department, New York City.

WELCH, ALEXANDER MCMILLAN, PH.B. (Arch.), . 1890.

11 East 42d St. and 15 E. Seventy-first St., New York City.

1890-91, in architect's office. 1891-93, McKim Fellow, travelling in Europe. 1893 to date, practicing architect. Summer of 1893 spent in Bodie, Cal., carrying on experimental tests on Chlorination for Standard Con. Mining Co., making tests and erecting Chlorination works for Jackson & Lakeview Mining Co., of Lundy, Cal. Also erected large Experimental Cyanide Plant for same company. Chemical Expert in Patent Litigation. Vacation of 1899 spent in visiting Mining and Metallurgical works in British Columbia.

WELLS, JAMES SIMPSON CHESTER, PH.B., PH.D., . 1875.

Columbia University, New York City, and Hackensack, N. J.

1875-79, Assistant in Quantitative Analysis, School of Mines. Vacation of 1877, spent as Night Superintendent Pennsylvania Lead works. 1879-93, Instructor in Analytical Chemistry, School of Mines.

WESTERVELT, WILLIAM YOUNG, E.M., . . . 1894.

100 William Street, New York City.

1894-95, Chemist and Surveyor, Ducktown Sulphur, Copper and Iron Co., Ltd. 1895-96, Engineer and Chemist, same company. 1896, Acting Mining Superintendent, same company. 1897, Superintendent of Mines, same company. January, 1898, resigned to join Mr. Wm. H. Case in formation of firm of Case & Westervelt, Consulting Mining Engineers. November same year, on account of death of partner, succeeded to the business of the firm. Am Consulting Engineer for the Ducktown Sulphur, Copper & Iron Co., Ltd., and in general practice have reported and started work on various properties in Tennessee, Georgia, New Mexico, New Jersey and Arizona.

WHEELER, HERBERT ALLEN, E.M., ... 1880.

1416 Chemical Building and 3124 Locust Street, St. Louis, Mo.

During 1880, Assistant Geologist in Utah, on U. S. Geological Survey. During 1881, Assistant Engineer Denver and Rio Grande Western Railroad, in Utah and Colorado, on location and construction. During 1882, Superintendent Vermont Copper Company, Ely, Vermont. From 1883 to 1894, Adjunct Professor of Mining at Washington University, St. Louis. Assistant Geologist Missouri Geological Survey. 1894 to date, Consulting Mining Engineer. 1896 to date, Secretary and Manager, Standard Tile Co. 1898 to date, President, Elizabeth Lead Co.

WHITE, ROBERT DAVIS, C.E., ... 1892.

Room 165, 32 Broadway, and 39 E. Seventy-fourth Street, New York City.

From April, 1899, to present time associated with R. W. Hildreth & Co., as Mechanical Engineer.

WHITE, THEODORE GREELY, A.M., PH.B., M.A., . 1894.

Department of Physics, 210 Fayerweather Hall, Columbia University, and 121 Madison Avenue, New York City.

Summer of 1893, working on the Geology of the Lake Champlain region. Summer of 1894, traveling and examining mining regions surrounding the Great Lakes in Canada and United States, also researches on the Geology of Mt. Desert Island, Maine. 1894 and 1895, Post-graduate student in Geology. Researches on the Trenton formation of the Lake Champlain Valley. 1895–96, Lecturer, N. Y. Board of Education. Summer 1897, N. Y. State Museum. Summer 1898, Researches on the Geology of the Boston Basin. 1896 to date, Assistant in Physics, Columbia University.

WHITE, WM. S., E.M., ... 1882.

Department of Docks, and Ferries, Pier A, North River, New York City, and Hillside Avenue, Englewood, N. J.

Assistant Engineer in charge of construction on the North River Water Front of New York City. 1899, Assistant Engineer Department of Docks and Ferries in charge of all construction on North River Water Front.

WHITING, LOWE, E.M., ... 1895.

Present address not known. If any member knows it please advise secretary of it.

WHITLOCK, HERBERT PERCY, C.E., ... 1889.

Assistant in Mineralogy, Columbia University School of Mines, and 449 Park Avenue, New York City.

WEICHMANN, FERDINAND G., PH.B., PH.D., . . 1881.

P. O. Box 79, Sta. W, Brooklyn, N. Y., and 771 West End Avenue, New York City.

Consulting Chemist American Sugar Refining Co., Brooklyn, N. Y.

WIENER, WILLIAM, A.M., PH.B., ... 1891.

Newark High School, and 62½ Nelson Place, Newark, N. J.

1891–92, Chemist to the Hanson, Van Winkle Co., Newark, N. J. 1892–93, Chemicals for Electro-plating. 17 and 19 Mechanic Street, Newark, N. J. 1893 to date, Instructor in Newark High School and general chemical Practice.

WILLIAMS, JOHN TOWNSEND, E.M., PH.B., . . 1873.

Architect and Builder, Lord's Court Building, 27 William Street, Room 1204, New York City, and Stamford, Conn.

WILLIAMS, WILLIAM FISH, C.E., E.M., . . . 1881.

City Engineer and 2 Court Street, New Bedford, Mass.

Chief Engineer, later also Assistant Manager to Cumberland Lands, Ltd., of Stewart County, Tenn. 1890–93, City Engineer, New Bedford, Mass. 1893 to

present time, also Chief Engineer at present on the construction of the New Bedford and Fairhaven Bridge.

WILLIS, BAILEY, E.M., C.E., ... 1878.
United States Geological Survey and 2117 Bancroft Place, Washington, D. C.

June, 1879, to July, 1881, Special Agent Tenth Census; sample of iron ores and student of iron deposits in States east of the Mississippi river. August, 1881, to June, 1884, Geologist in charge of Pacific division of Northern Transcontinental Survey, chiefly engaged in coal explorations in Washington, Oregon and Montana. July, 1884, to February, 1889, Assistant Geologist, U. S. Geological Survey, working in Tennessee and North Carolina. March, 1889, to June, 1893, Geologist in charge of Appalachian division, U. S. Geological Survey, directing work and studying geologic problems of the Palæozoic rocks south of Pennsylvania. 1891-93, Editor of Geologic Maps for Folios of the Geologic Atlas of the United States. In 1895-96, Geologist in charge of operations in the Cascade Range and Puget Sound Basin, Washington.

WILSON, HERBERT M., C.E., ... 1881.
U. S. Geological Survey, Washington, D. C.

1881-82, Leveller and Transitman, afterwards Chief of Preliminary party, S. & D. R. R. Mexico. 1882-88, Topographer U. S. Geological Survey. 1889-90, Division Engineer, U. S. Irrigation Surveys. 1891, Geographer, U. S. Geological Survey. 1894, Chief Geographer. 1897, Geographer in charge of Atlantic Section.

WILSON, WILLIAM ALEXANDER, E.M., . . . 1882.
Chamber of Commerce, Salt Lake City, Utah.

Assayer for two and a-half years. Superintendent of Sampling Mill for two years. Superintendent of 30-Stamp Mill (dry crushing, chloridizing, amalgamating and lixiviating capacity sixty tons per day) for five years. Specialty, treatment of silver and gold ores and examining and reporting on mining properties. Superintending of Mining or Milling operations. U. S. Deputy Mineral Surveyor.

WILTSEE, ERNEST ABRAM, E.M. . . . . 1885.
Crocker Building, San Francisco, Cal.

1885-86, Assistant Chemist Edgar Thompson Steel Works, Braddock, Pa. 1886, to May, 1887, Chemist Colorado Coal and Iron Company, Pueblo, Col. May, 1887, to August, 1888, Chemist for the Globe Smelting and Refining Company, Denver, Col. August, 1888, to April, 1890, Assistant Superintendent North Star Mining Company, Grass Valley, Cal. April, 1890 to 1891, Superintendent Menlo Mines, Grass Valley, Cal. January, 1892, Expert work, Nevada County, Cal. January to August, 1892, with California State Mining Bureau. August, 1892, to January, 1893, Expert work through California. April, 1893, Manager Gold Mines for Barnato Bros., Johannesburg, South Africa. July 1, 1894, Eldenhuis Est. and Gold Mining Co., Johannesburg, South African Republic.

WITTMACK, CHARLES AUGUSTUS, M.S., Ph.B., PH.D., . 1882.
1 West 102d Street, New York City.

WOOLSON, IRA HARVEY, E.M., ... 1885.
Columbia University, New York City.
1885-86, Assistant Geological Survey of New Jersey. 1886-87, Assistant Assay Department, School of Mines. 1887-89, Assistant, Drawing Department, School of Mines. 1891 to date, Instructor Mechanical Engineering, Columbia University.

Y.

YRIZAR, ROBERTO, E.M., ... 1895.
A. P. 27 Zacatecas, Mexico, also care C. Viaders, 14–16 South William Street, New York City.

YOUNG, EDWARD LEAVITT, E.M., ... 1882.
American Buyer Takata & Co., of Tokio, Japan; 10 Wall Street, and 317 W. Eighty-ninth Street, New York City.

HONORARY MEMBERS.

BURR, WM. H.
Professor Civil Engineering, Columbia University. Address, 161 W. Seventy-fourth Street, New York City.

CHANDLER, CHARLES F., PH.D., M.D., LL.D.
Professor of Chemistry, Columbia University. Address, 51 E. Fifty-fourth Street, New York City.

HOWE, HENRY M.
Professor of Metallurgy, Columbia University. Address, 27 W. Seventy-first Street, New York City.

MILLER, GEORGE M., A.M., LL.B.
West Nyack, New York.

ROOD, O. N., A.M.
Professor of Physics, Columbia University. Address, Columbia University, New York City.

VAN AMRINGE, J. H., PH.D., L.H.D., LL.D.
Professor of Mathematics, Columbia University. Address, 66 W. Forty-seventh Street, New York City.

WARE, WILLIAM R., LL.D.
Professor of Architecture, School of Mines, Columbia University. Address, 126 E. Twenty-eighth Street, New York City.

HONORARY MEMBERS DECEASED.

AGNEW, C. R.,	1888.
BARNARD, F. A. P.,	1889.
NEWBERRY, J. S.,	1892.
PECK, W. G.,	1892.
RUTHERFURD, LEWIS M.,	1892.
TROWBRIDGE, W. P.,	1892.
FISH, HAMILTON,	1893.
EGLESTON, THOMAS,	1899.

LIST No. 3.

Contains the names of Graduates of the School of Mines, not members of the Alumni Association, nor participating in the benefits of such membership. For this reason great uncertainty prevails as to many of the addresses given, which are the best at hand, and should any corrections be noted the Secretary will be glad to be advised of them.

It is very desirable that this list should be shortened as far as practicable by the transfer of names from it to the preceding List, No. 2, under the Rules.

(Revised to January, 1900.)

Acken, J. B., Ph.B., ... 1894.
Hawarth, N. J.

Adams, W. C., C.E., ... 1884.
47 West 28th Street, New York City.

Adams, W. J., A.M., E.M., ... 1878.
Room 14, 434 California Street, San Francisco, Cal.

Agramonté, E., C.E., ... 1886.
110 Lexington Avenue, New York City.

Agramonté, I.E., C.E., ... 1883.
Zulieta No. 3, Havana, Cuba.

Agramonté, José Cesar, C.E., ... 1886.
Address unknown.

Alden, Herbert C., E.M., ... 1884.
Address unknown.

Aldrich, C. H., Ph.B., ... 1893.
8 Cushing Street, Providence, R. I.

Allen, C. S., Ph.B., M.D., ... 1874.
Address unknown.

Anderson, George Mendenhall, Ph.B., ... 1891.
East Walnut Hills, Cincinnati, Ohio.

Andresen, Charles Alfred, E.M., ... 1881.
Pickard & Andresen, 89 Gold Street, New York City.

Anthon, C. L., E.E., ... 1898.
220 East 123d Street, New York City.

Appleby, John Storm, Ph.B., A.M., ... 1888.
Architect, 216 West 59th Street, New York City.

Arendt, M., E.E., ... 1898.
42 West 126th Street, New York City.

Arden, John L., Ph.B., E.E., ... 1896.
Garrison, N. Y.

Aschman, Fred. Theo., Ph.B., ... 1881.
Chemist and Professor of Chemistry, College of Pharmacy.

Auryansen, Fredh., C.E., ... 1896.
Piermont, N. Y.,
and 86 Water Street, Pittsburg, Pa.

Ayestas, Alberto, Ph.B., ... 1883.
Tegucicalpa, Honduras, C. A.

Aylmer-Small, C. S., E.E., ... 1899.
Passaic Bridge, N. J.

Ayres, W. C., Ph.B., ... 1893.
Address unknown.

Baker, George L., Ph.B., ... 1888.
Address unknown.

Bardwell, A. F., E.M., ... 1886.
Box 773, Aspen, Colo.

Barnard, Aug. Porter, E.M., ... 1868.
125 East 26th Street, New York City.

Barnes, W. C., E.E., ... 1897.
Morristown, N. J.

Barros, Louis de Souza, E.M., C.E., ... 1877.
Address unknown.

Bartlett, F. R., C.E., ... 1880.
344 Madison Street, Brooklyn, N. Y.

Baxter, D. E., C.E., ... 1897.
32 West Sixtieth Street, New York City.

Beadel, H. L., B.S., ... 1898.
120 Front Street, New York City.

Beckstein, Charles Alfred, Ph.B., ... 1888.
336 West Forty-sixth Street, New York City.

Beckwith, Charles Ellsworth, Met.Eng., ... 1888
Address unknown.

Beckwith, George Alexander, C.E., ... 1890.
Paterson, N. J.

Behlem, Herman, Ph.B., ... 1890.
125 East One Hundred and Fifteenth Street, New York City.

Behr, Edward, C.E., ... 1877.
426 Henry Street, Brooklyn, N. Y.

Bell, Henderson M., Jr., E.M., ... 1886.
Brambell, Mercer Co., W. Va.

Bellman, J. J., E.E., ... 1897.
90 King Street, New York City.

Bemis, F. P., ... 1885.
Whitaker Block, Davenport, Iowa.

Benedict, Eli, B.S., ... 1899.
86 Convent Avenue, New York City.

Bennett, G. L., M.E., ... 1898.
208 Putnam Avenue, Brooklyn, N. Y.

Bentley, W. A., M.E., ... 1898.
161 West 108th Street, New York City.

Bergen, Chas. Hill, C.E., ... 1892.
Red Bank, N. J.

Berger, John, B.S., C.E., ... 1899.
342 East 4th Street, New York.

Berry, Gerald, C.E., ... 1889.
78 Morton Street, Brooklyn, N. Y.

Black, Alex L., E.M., ... 1890.
56 Carondelet Street, New Orleans, La.

Bliss, Collins Pechin, Ph.B., ... 1891.
60 Cedar Street, Room 9, New York City.

Blondel, T., Jr., B.S., ... 1899.
548 Mott Avenue, New York City.

Blum, E., B.S., ... 1899.
1024 Park Avenue, New York City.

Blydenburgh, Chas. E., A.B., A.M., E.M., ... 1878.
Box 180, Rawlings, Wyoming.

Boehm, Geo. A., Ph.B., ... 1897.
33 West 89th Street, New York City.

Bolles, Randolph, Ph.B., ... 1892.
Englewood, N. J.

Bolton, Robert, Ph.B., M.D., ... 1879.
Assistant Physician, Essex County Insane Asylum, So. Orange Av., Newark, N. J.

Bossange, E. R., Ph.B., ... 1893.
75 West Forty-fifth Street, New York City.
Bostwick, W. A., M.E., ... 1898.
324 West Forty-sixth Street, New York City.
Boyd, J. D., B.S., ... 1899.
308 West 73d Street, New York City.
Brennan, Andrew Joseph, C.E., ... 1885.
Address unknown.
Bridgham, Samuel Willard, E.M., ... 1867.
49 West Twenty-third Street, New York City.
Brickerhoff, George Charles, E.M., ... 1878.
Apartado 183, Matanzas, Cuba.
Bronson, Edward Stelle, A.B., A.M., E.M., ... 1867.
49 Garden Place, Brooklyn, N. Y.
Brooks, W. F., Ph.B., ... 1893.
335 West Fifty-fifth Street, New York City.
Brosnan, F. X., C.E., ... 1891.
146 West Seventy-fourth Street, New York City.
Brown, Alex. M., E.M., ... 1897.
245 West Fifty-fourth Street, New York City.
Brown, F. G., E.M., ... 1867.
15 Whitehall Street, New York City.
Brown, H. D., C.E., ... 1898.
9 West 129th Street New York City.
Browning, J. H. B., M.D., ... 1880.
Smithtown, L. I., N. Y.
Bruckman, Frederick, E. M., ... 1867.
U. S. Mint and 120 West Third Avenue, Denver, Colo.
Brugman, Wm. F., Ph.B., ... 1880.
Los Angeles, California.
Bryce, Wm., Jr., Ph.B., ... 1884.
40 West Fifty-fourth Street, New York City.
Buckingham, Frederick Endicott, E.M., ... 1884.
Department Public Works, Brooklyn, N. Y.
Buckland, Will. A., Ph.B., ... 1890.
36 East Twenty-second Street, New York City.
Bullman, Chas., Ph.B., ... 1883.
808 3d Place, Plainfield, N. J.
Burnside, C. H., B.S., ... 1898.
372 W. 120th Street, New York City.
Burrill, Percy M., E.M., ... 1896.
Bartow-on Sound, N. Y., and 56 East 49th Street, New York City.
Burritt, W. W., ... 1884.
Englewood, N. J.
Burroughs, H. S., E.E., ... 1897.
1416 Pacific Street, Brooklyn, N. Y.
Bush, E. R., E.M., ... 1881.
104 John Street, New York City.
Bush, William Falkner, E.M., ... 1885.
Address unknown.

Butler, N., E.M., ... 1880.
Glen Ridge, N. J.

Butler, Wm. C., Met.E., ... 1887.
Everett, Wash.

Cady, Linus B., E.M., C.E., ... 1877.
Address unknown.

Cairns, B. S., A.B., B.S., ... 1899.
40 Grove Street, New York City.

Campbell, Alonzo Clarence, E.M., ... 1869.
Mining Engineer, 306 Russell Street, Nashville, Tenn. Specialty, Milling and Concentration.

Campbell, A. J., E.M., ... 1898.
120 West 81st Street, New York City.

Canfield, A. E., E.M., ... 1877.
Address unknown.

Canfield, M. C., E.E., ... 1893.
18 Clinton Street, Cleveland, Ohio.

Carney, Edward J., C.E., ... 1896.
67 West 68th Street, New York City.

Carpenter, H. C., C.E., ... 1899.
113 East 69th Street, New York City.

Carrère, Joseph Maxwell, C.E., ... 1883.
36 Park Place, New York City, and New Brighton, N. Y.

Carson, Joseph, C.E., ... 1890.
31 West Fifty-fifth street, New York City.

Cary, Geo. B., Ph.B., ... 1895.
184 Delaware Avenue, Buffalo, N. Y.

Chapman, A. W., E.E., A.B., ... 1894.
160 Hicks Street, Brooklyn, N. Y.

Chapman, H., B.S., ... 1899.
369 West 120th Street, New York City.

Chatain, H. G. F. J., E.E., ... 1897.
42 West Ninetieth Street, New York City.

Chazel, P. E., ... 1881.
56–58 Broad Street, Charleston, S. C.

Clark, F. S., E.M., Ph.D., ... 1885.
527 Madison Avenue, New York City.

Clark, J. H., E.M., ... 1897.
Paterson, N. J.

Clark, Leroy, Jr., E.E., ... 1894.
227 West 28th Street and 208 West 85th Street, New York City.

Clark, W. G., E.E., ... 1899.
37 East 50th Street, New York City.

Clayton, William Robert, Ph.B., ... 1890.
Architect, 31 and 32 Rialto Building, Chicago, Ill.

Cogan, H. M., E.E., ... 1899.
Bay Ridge, N. J.

Collins, C. L., 2d, E.E., ... 1897.
323 Palisade Avenue, Yonkers, N. Y.

Cloud, Leo George, A.B., E.M., ... 1879.
216 Mammouth Street, Newport, Ky.

Colt, S. B., Ph.B., ... 1888.
1197 Broad Street, Newark, N. J.

Colton, Frederick Gray, Ph.B., ... 1890.
136 Montague Street, Brooklyn, N. Y.

Comstock, Claude Nichols, C.E., ... 1888.
Address unknown.

Congdon, H. W., Ph.B., ... 1897.
194 Clinton Street, Brooklyn, N. Y.

Constant, Charles Louis, E.M., C.E., ... 1877.
32 Park Street, Jersey City, N. J.

Corcoran, J. T., E.M., ... 1884.
131 Smith Street, Brooklyn, N. Y.

Cornell, George B., E.M., C.E., ... 1877.
29 Broadway and 46 West 48th Street, New York City.

Cornwall, George Rockwell, E.M., C.E., ... 1876.
189 Lefferts Place, Brooklyn, N. Y.

Cornwall, H. C., E.M., ... 1879.
Commonwealth Ins. Co., Nassau Street, New York City.

Coursen, George Hampton, E.M., C.E., ... 1868.
Address unknown.

Covell, E. C., A.B., ... 1892.
Address unknown.

Covell, W. S., Ph.B., ... 1893.
42 West 66th Street, New York City.

Coykendall, Thomas Cornell, C.E., ... 1890.
Rondout, N. Y.

Cozzens, Harmon, E.M., ... 1885.
Address unknown.

Crampton, S. H., E.E., ... 1897.
95 Gates Avenue, Brooklyn, N. Y.

Crawford, H. E., ... 1899.
220 West 28th Street, New York City.

Cristy, Edward Buxton, Ph.B., ... 1891.
Albuquerque, New Mexico.

Cromwell, James William, Jr., Ph.B., ... 1889.
Architect, 29 Brevoort Place, Brooklyn, N. Y.

Crowell, Charles B., Ph.B., ... 1885.
Minneapolis, Minn.

Curtis, C. C., A.B., A.M., ... 1892.
Address unknown.

Curtis, Charles Gordon, C.E., ... 1881.
President Curtis Electrical Mfg. Co., Whiton Street, Jersey City, N. J.

Darrach, J. M. A., Ph.B., ... 1896.
Morristown, N. J.

Davis, William Monroe, E.M., ... 1890.
Syracuse, N. Y.

Del Calvo, Francis, C.E., ... 1884.
Address unknown.

Delson, I., C.E., ... 1899.
203 East 69th Street, New York City.

Dickerson, F. S., E.E., ... 1899.
Great Neck, Long Island, N. Y.

Dieterich, A. E., C.E., ... 1899.
963 Fifth Avenue, New York City.

Dodsworth, W. A., Ph.B., ... 1888.
19 Beaver Street, New York City.

Donnell, H. E., Ph.B., ... 1887.
Address unknown.

Doolittle, Charles Horace, E.M., ... 1885.
Address unknown.

Dowie, Horace, A.B., E.E., ... 1896.
363 Jefferson Avenue, Brooklyn, N. Y.

Downing, Orrien Pinkerton, Ph.B., ... 1878.
116 Battery Street, San Francisco, Cal.

Dunn, A. D., E.E., ... 1898.
164 West 111th Street, New York City.

Dunn, Ganno Sillick, B.S., E.E., ... 1891.
Elect Engineer, Crocker-Wheeler Electric Co., Ampere, East Orange, N. J.

Durham, Edward B., E.M., ... 1892.
Mt. Kisko, N. Y.

Durham, L., C.E., ... 1899.
162 West 27th Street, New York City.

Dutcher, B. H, Ph.B., ... 1892.
Asst. Surgeon, U. S. A., Ft. Leavenworth, Kansas.

Easton, L. C., C.E., ... 1884.
516 Lincoln Building, Los Angeles, Cal.

Eastwick, Edward P., Jr., Ph.B., C.E., ... 1896.
Am. Sug. Ref. Co., New Orleans, La.

Eddie, E. C., E.M., ... 1885.
Address unknown.

Ehrenreich, J. J., E.E., ... 1899.
48 East 74th Street, New York City.

Eliot, Walter Greame, E.M., C.E., Ph.B., Ph.D., ... 1878.
"University Magazine," 70 South Street, and University Club, New York City.

Ellis, A. Van Horn, C.E., ... 1889.
Bartow-on-Sound, N. Y.

Emanuel, L. V., C.E., ... 1896.
925 Park Avenue, New York City.

Emery, G. H., Ph.B., ... 1894.
18–20 West 34th Street, New York City, and Nyack, N. J.

Ents, G. G., B.S., ... 1899.
24 East 83d Street, New York City.

Escobar, Francisco, E.M., ... 1889.
842 Wilson Avenue, Cleveland, Ohio.

Fales William, E. S., E.M., LL.B., ... 1871.
Amoy, China.

Falk, D. B., C.E., ... 1882.
Savannah, Ga.

Falk, M. S., C.E., ... 1899.
995 Madison Avenue, New York.

Farmer, A. S., C.E., ... 1897.
147 South Fifth Street, Brooklyn, N. Y.
Fechheimer, A. L., B.S., ... 1899.
57 West Fifty-sixth Street, New York City.
Fellows, William K., Ph.B., ... 1894.
1733 Marquette Building, Chicago, Ill.
Fenner, Clarence Norman, E.M., ... 1892.
Paterson, N. J.
Ferguson, G., C.E., ... 1898.
Paterson, N. J.
Ferguson, George Albert, Ph.B., ... 1890.
138 Wilson Street, Brooklyn, N. Y.
Ferguson, Samuel, B.S., E.E., ... 1899.
202 West 103d Street, New York.
Fuentes, Paul, E. M., ... 1894.
Address unknown.
Fisher, Lloyd Weigand, Ph.B., ... 1890.
109 E. Twenty-eighth Street, New York City.
Fitch, Charles Lincoln, E.M., ... 1882.
Address unknown.
Fitch, Josiah Huntington, E.M., ... 1884.
Address unknown.
Fitzgerald, George, E.M., ... 1884.
El Paso, Texas.
Floyd, F. W., C.E., M.M., ... 1877.
529 West Twentieth Street, New York City.
Force, D. N., Jr., E.E., ... 1897.
Montclair, N. J.
Fowler, A. C., C.E., ... 1889.
Cienfuegos, Cuba.
Francke, Robert Otto, C.E., ... 1880.
W. Passburg, Esq., Moscow, Russia.
Frankfield, Emil, C.E., ... 1886.
328 W. Fifty-sixth Street, New York City.
Franklin, L. M., Jr., Ph.B., ... 1896.
Flushing, L. I., N. Y.
Frisbee, H. D., E.E., ... 1894.
Fulton Street, New York City.
Fuentes, Paul, E.M., ... 1894.
321 Hudson Street, Hoboken, N. J.
Fulton, C. H., E.M., ... 1897.
229 Fifth Avenue, Brooklyn, N. Y.
Gage, Samuel Edson, Ph.B., ... 1887.
Architect, 144 Fifth Avenue, New York City.
Gallatin, A. R., A.B., E.E., ... 1898.
58 W. Fifty-fifth Street, New York.
Gardner, Watts Denning, C.C., ... 1888.
Board of Health, New York City.
Garrison, Edmund Hoyt, E.M., C.E., ... 1876.
84 Highland Street, Yonkers, N. Y.

Geer, George Jarvis, Jr., E.M., ... 1868.
Merchant, 453 Broome Street, New York City.
Geppert, R. M., E.M., ... 1898.
20 Mercer Street, Newark, N. J.
Giddings, Edward Everett, E.M., ... 1867.
Merchant, 413 Royal Insurance Building, Chicago, Ill.
Gill, A. W., C.E., ... 1897.
Leonia, N. Y.
Goodman, M., C.E., ... 1898.
338 E. Fourth Street, New York City.
Goodridge, J. W., C.E., ... 1897.
Brooklyn, N. Y.
Goldsmith, Byron Benjamin, Ph.B., ... 1887.
19 E. Seventy-fourth Street, New York City.
Goldsmith, Goldwin, Ph.B., ... 1896.
New Rochelle, N. Y.
Gould, Edward Ludlow, C.E., ... 1890.
59 Hawthorne Avenue, Yonkers, N. Y.
Gotthelf, A. H., Ph.B., ... 1897.
Hastings, N. Y.
Gottschall, L., B.S., ... 1898.
207 East Fifty-third Street, New York City.
Greene, Wilkins Updike, Ph.B., ... 1880.
104 Columbia Heights, Brooklyn, N. Y.
Gregory, L. E., C.E., ... 1893.
406 Passaic Avenue, Kearney, N. J.
Griffin, S. P., Jr., ... 1884.
449 Park Avenue, New York City.
Griffiths, Vincent Colyer, Ph.B., ... 1889.
160 Herkimer Street, Brooklyn, N. Y.
Griggs, Wilfred Elizur, Ph.B., ... 1889.
Architect, Waterbury, Conn.
Griswold, Wm. T., C.E., ... 1881.
U. S. Geol. Survey, Washington, D. C.
Haas, Harry Leopold, Ph.B., ... 1878.
Carrére and Haas, 36 Park Place, New York City.
Haldy, George F., E.E., ... 1897.
Cleveland, Ohio.
Hall, H., B.S., ... 1899.
204 Hancock Street, Brooklyn, N. Y.
Hamilton, Schuyler, Jr., A.B., A.M., E.M., ... 1876.
Croton-on-Hudson, Westchester Co., N. Y., Architect and Brick M'f'r.
Hanson, R. C., C.C., ... 1894.
79 Manhattan Avenue, New York City.
Harker, Charles Sumner, E.M., ... 1879.
26 Montgomery Street, San Francisco, Cal.
Harmer, Thomas Hays, A.B., A.M., E.M., ... 1867.
113 East Twenty-seventh Street, New York City.
Harrison, Newton, E.E., ... 1892.
Electrical Engineer, 136 Liberty Street, New York City.

Hart, Burnham, C.E., ... 1885.
Ramsay, N. J.

Hart, Charles Henry, C.E., ... 1890.
199 Lennox Avenue, New York City.

Hasegawa. Yothinosuke, E.M., Ph.D., ... 1878.
Mitsu Bishi Sha, No. 11, Awajicho, Nichome Konda, Tokio, Japan.

Hawkes, Emil McDougal, A.B., E.M., ... 1885.
267 Fifth Avenue, New York City.

Hawkins, S. O., B.S., ... 1899.
61 Lefferts Place, Brooklyn, N. Y.

Hawks, H. D., E.E., ... 1896.
40 West Fifty-fifth Street, New York City.

Hay, Arthur, E.M., ... 1882.
821 South Second Street, Springfield, Ill.

Heike, R. E., B.S., ... 1899.
256 Montgomery Street, Jersey City, N. J.

Heinze, Frederick Augustus, E.M., ... 1889.
General Manager, Montana Ore Purchasing Co., Butte, Montana.

Herckenrath, W. A., E.M., C.E., ... 1892.
Address unknown.

Henderson, H. H., C.E., ... 1899.
87 Locust Hill Avenue, Yonkers, N. Y.

Hesselbach, Chas. V., C.E., ... 1896.
93 Lexington Avenue, New York City.

Hemmer, Frederick Adolph, Ph.B., ... 1881.
Box 6, Edgewater, N. J.

Herz, Henry, Ph.B., ... 1897.
176 Newark Avenue, Jersey City, N. J.

Heye, George G., E.E., ... 1896.
11 East 48th Street, New York City.

Hill, R. F., Jr., E.M., ... 1898.
31 East 75th Street, New York City.

Hodgson, E. H., B.S., ... 1898.
417 West 117th Street, New York City.

Hooker, William H., A.B., A M., E.M., ... 1869.
145 Broadway, New York City.

Hooper, Louis Mosher, C.E., ... 1880.
Rutherford, N. J.

Holbrook, F. M., E.E., ... 1897.
Columbia University, New York.

Hollerith, Herman, E.M., Ph.D. (1890), ... 1879.
Genl. Mgr. The Tabulating Co., 1054 31st Street, Washington, D. C.

Holter, Norman Bernard, E.M., ... 1891.
A. M. Holter, Hardware Co., Helena, Mont.

Horn, James Thurston, A.B., C.E., ... 1884.
Naval Architect, and 13 East Fifty-third Street, New York City.

Hornbostel, Henry Frederick, Ph.B., ... 1891.
39 Second Place, Brooklyn, N. Y.

How, R. W., Jr., C.E., ... 1898.
Wantagh, L. I., N. Y.

Hoyt, John Sherman, C.E., ... 1890.
934 Fifth Avenue, New York City.

Hoyt, R., C.E., ... 1893.
Katonah, N. Y.

Hoyt, W. L., C.E., ... 1876.
Globe Smelting and Refining Co., Denver, Col.

Hudson, Edward Henry, C.E., ... 1889.
Address unknown.

Hudson, P. K., E.M., ... 1899.
1 East 76th Street, New York City.

Hulbert, C. S., E.E., ... 1899.
3 East 14th Street, New York City.

Humbert, W. S., E.M., ... 1883.
Niagara Falls, N. Y.

Humphreys, J. B., E.E., ... 1897.
23 East 47th Street, New York City.

Huntington, F. W., E.M., ... 1885.
Address unknown.

Huntting, Henry Ogden, Ph.B., ... 1887.
Architect, 454 Ceasson Avenue, Brooklyn, N. Y.

Hurlbert, E. D., Jr., C.E., ... 1890.
106 Hicks Street, Brooklyn, N. Y.

Hutchins, G. L., E.M., ... 1898.
Address unknown.

Hyatt, Charles Edw., E.E., ... 1896.
Newark, N. J.

Ihlseng, M. C., C.E., Ph.D., ... 1875.
State College, Pa.

Ives, Arthur Stanley, C.E., E.E., ... 1888.
33 Sydney Place, Brooklyn, N. Y.

Jackson, Charles Edward, C.E., ... 1875.
15 Cortlandt Street, New York City.

Jacobs, H. A., Ph.B., ... 1894.
107 East 78th Street, New York City.

Jarman, Z. H., C.E., ... 1895.
112 Lefferts Place, Brooklyn, N. Y.

Jarmulowsky, Meyer, Ph.B., ... 1890.
27 Jefferson Street, New York City.

Jenny, Walter Proctor, E.M., Ph.D., ... 1869.
Rapid City, South Dakota.

Jeup, B. J. F., C.E., ... 1887.
119 Walcott Street, Indianapolis, Ind.

Joffe, Meyer, C.E., ... 1894.
Address unknown.

Jones, Thomas Jefferson, Met.Eng., ... 1890.
Pulaski City, Va.

Jones, William D., Ph.B., ... 1888.
206 Produce Exchange, New York City.

Jones, W. P., E.E., ... 1898.
312 West 28th Street, New York City.

Jordao, Jos. Nabor Pacheco, C.E., E.M., Ph.B., ... 1877.
Address unknown.

Judd, Charles Breck, E.M., ... 1881.
Westinghouse Building, Pittsburg, Pa.

Judson, Hanford Chase, E.E., ... 1898.
Dobbs Ferry, N. Y.

Karr, C. P., Ph.B., ... 1878.
1 Union Square, West, New York City.

Kaufmann, Edwin, Ph.B., ... 1897.
49 East 66th Street, New York City.

Keeler, Frederick Sterling, Ph.B., ... 1891.
530 Bouch Avenue, Buffalo, N. Y.

Kelly, William, A.B., E.M., ... 1877.
President Lake Superior Mining Imp. Co., Vulcan, Dickinson Co., Mich.

Kilian, William G., Ph.B., ... 1897.
352 West 33d Street, New York City.

King, Charles, Ph.B., ... 1876.
Railroad contractor, King & Dickinson, Tacoma, Wash.

Kletchka, John Joseph, A.B., C.E., ... 1892.
247 Willis Avenue, New York City.

Knapp, John Augustus, A.B., A.M., E.M., ... 1870.
Chicago and Aurora Smelting Co., Chicago, Ill.

Kneeland, F. R., B.S., ... 1899.
239 W. 74th Street, New York City.

Knox, Charles E., E.E., ... 1892.
Jas. W. Queen & Co., Philadelphia, Pa.

Koch, Richard, E.E., ... 1897.
47 East 78th Street, New York City.

Kohn, Robert David, Ph.B., ... 1890.
4 Rue Honoré Chevalier, Paris, France.

Korn, Louis, Ph.B., ... 1890.
261 Broadway, New York City.

Kraemer, Henry, Ph.G., Ph.D., ... 1895.
Professor of Botany, Philadelphia College of Pharmacy, Philadelphia, Pa.

Krumb, H., ... 1898.
55 Ten Eych Street, Brooklyn, N. Y.

Lane, Russell, B.S., ... 1897.
325 Lincoln Avenue, Orange, N. J.

Langmuir, A. C., ... 1893.
Waverly, N. J.

Leavens, H. W., E.M., ... 1875.
Broken Hill Refinery Co., Bort Pirie, Australia.

Leeming, Thomas Lonsdale, Ph.B., ... 1894.
73 Warren Street, New York, and 25 Montgomery Street, Brooklyn, N. Y.

Ledoux, Augustus Damon, Ph.B., ... 1881.
P. O. Box 426, Richmond, Va.

Lee, Henry Charles, C.E., ... 1886.
127 East 21st Street, New York City.

Lewis, C. McK., ... 1898.
104 East 37th Street, New York City.

Lichtenstein, Edward Gervaise, Ph.B., ... 1890.
14 West 74th Street, New York City.
Lichtenstein, Howard, E.E., ... 1898.
132 Amity Street, Brooklyn, N. Y.
Lindsley, Stewart, E.M., ... 1870.
Orange, N. J.
Livingston, Goodhue, Ph.B., ... 1892.
George B. Post, Century Building, New York City.
Livingston, J., Jr., E.E., ... 1898.
56 East 49th Street, New York City.
Lobo, G., E.E., ... 1898.
219 West 44th Street, New York City.
Lord, Nathaniel Wright, E.M., ... 1876.
Professor Mining and Metallurgy, Ohio State University, Columbus, O.
Lowenburg, L., Ph.B., E.E., ... 1898.
360 W. 120th Street, New York City.
Lowndes, William Shepherd, Ph.B., ... 1890.
42 Sherman Place, Jersey City, N. J.
Lucas, G. L., C.E., ... 1898.
Kingsbridge, N. Y.
Luttgen, Eberhard, Ph.B., ... 1884.
Wyncote P. O., Pa.
McClelland, J. B., Ph.B., ... 1897.
2 West 47th Street, New York City.
McClur, W. J., E.E., ... 1898.
259 West 52d Street, New York City.
McCulloch, R. A., B.S., ... 1899.
258 W. 73d Street, New York City.
McCulloh, E. A., Ph.B., ... 1878.
Glencoe, Md.
McDowell, Frederick H., E.M., ... 1872.
Address unknown.
McIlvain, Alexis Reed, Ph.B., ... 1888.
Architect, 48 Exchange Place, New York City.
McIntyre, H. K., E.E., ... 1899.
303 W. 74th Street, New York City.
McKee, H. S., E. M., ... 1893.
Los Angeles Terminal Railway Company, Los Angeles, Cal.
McKilay, James Buell, E.M., ... 1892.
108 West 79th Street, New York City.
McKleroy, William Henry, Met. Eng., ... 1892.
Cashier Anniston National Bank, Anniston, Ala.
McLean, J. M., E.E., ... 1897.
204 West 36th Street, New York City.
McLellan, H., B.S., ... 1898.
108 East 18th Street, New York City.
McNeil, Charles R., Ph.B., ... 1894.
912 West End Avenue, N. Y., and Litchfield, Conn.
MacGahan, Paul, E.E., ... 1896.
523 Kelly's Avenue, Wilkinsburg, Pa.

MacGregor, Donald, Ph.B., ... 1896.
118 Madison Avenue, New York City.
MacMullen, C. W., E.E., ... 1897.
52 West 161st Street, New York City.
MacTague, John J., E.M., ... 1883.
Address unknown.
Maben, J. C., Jr., E.E., ... 1897.
279 Lexington Avenue, New York City.
Macy, V. E., Ph.B., ... 1893.
18 West 53d Street, New York City.
Madden, J. H., C. E., ... 1897.
308 West 30th Street, New York City.
Magalhaes, G. W., E.E., ... 1897.
Flatbush, N. Y.
Maghee, John Holme, A.B., A.M., C.E., ... 1876.
Cayuga Lake Ice Line, Rochester, N. Y., and 29 East 32d Street, New York City.
Mahl, J. Thomas, C.E., ... 1891.
G. H. and S. A. R. R. Co., Houston, Texas.
Mainzer, H. R., B.S., ... 1899.
9 East 66th Street, New York City.
Manheims, L. R., E.E., ... 1897.
164 East 79th Street, New York City.
Mann, C. R., A.B., A.M., ... 1897.
Address unknown.
Mann, Horace Borchsenius, Ph.B., ... 1890.
Orange, N. J.
Mapes, Charles Halstead, Ph.B., ... 1889.
60 West 40th Street, New York City.
Matthew, W. D., Ph.B, ... 1892.
St. John, N. B., Canada.
Matthews, Charles Thompson, Ph.B., ... 1889.
Architect, Elm Park, Norwalk, Conn.
Matsui, Nawokichi, Ph.B., Ph.D., ... 1878.
Agricultural College, Konaba, Tokio, Japan.
Mattison, Joseph Godley, Ph B., ... 1880.
Real Estate and Insurance Broker, 20 West 14th Street, New York City.
Meikleham, Thomas Mann Randolph, C.C., ... 1890.
Columbia Electrical Supply Co., 339 Fourth Avenue, New York City.
Merwin, H. J., E. M., ... 1879.
Middlesborough, Ky.
Mesa, Antonio Esteban, C.E., ... 1882.
Address unknown.
Mears, George K., E.E., ... 1894.
Elizabeth, N. J.
Metzger, Arthur, Ph.B., ... 1896.
43 East 72d Street, New York City.
Milliken, G. F., E.M., ... 1879.
Union League Club, New York City.
Mitchell, H. B., ... 1898.
164 Washington Place, Brooklyn, N. Y.

Moeller, Rudolph, Ph.B., ... 1887.
336 West 29th Street, New York City.
Monell, Ambrose, Jr., E.E., ... 1896.
43 Lafayette Place, New York City.
Montgomery, H. P. A., Ph.B., ... 1896.
1189 Madison Avenue, New York City.
Morgan, J. L., Ph.B., ... 1888.
47 Fulton Street, New York City.
Morewood, George Barrow, E.M., Ph.D., ... 1878.
156 West Seventy-sixth Street, New York City.
Morewood, Henry Francis, E.M., Ph.D., ... 1876.
Importer, Box 2088, New York City.
Mortimer, L. N., E.E., ... 1898.
54 West Twenty-first Street, New York City.
Morris, B. W., Jr., Ph.B., ... 1896.
33 West Forty-second Street, New York City.
Morse, George T., Ph.B., ... 1896.
613 Carleton Avenue, Brooklyn, N. Y.
Moschowitsch, M., E.E., M.E., ... 1899.
1560 Avenue A, New York City.
Munoz del Monte, A. C., C.E., Ph.D., ... 1888.
328 Chestnut Street, Philadelphia, Pa.
Munroe, M., E.E., ... 1894.
Address unknown.
Murchison, K. M., Jr., Ph.B., ... 1894.
46 West Fifty-seventh Street, New York City.
Murphy, G. R., A.M., E.E., ... 1899.
West Hoboken, N. Y.
Murphy, J. G., E.M., C.E., ... 1877.
Grand Union Hotel, New York City.
Murray, George, E.M., ... 1874.
235 West Twenty-third Street, New York City.
Nambu, Kingo, E.M., ... 1878.
Nagasaki, Japan.
Necarsulmer, Edward, Ph.B., ...
109 East 70th Street, New York City.
Neftel, Knight, C.E., Ph.D., ... 1879.
115 Broadway, New York City.
Nettre, L. R., E.M., ... 1869.
26 Coventry Street W., London, England.
Newberry, S. B., E.M., Ph.D., ... 1878.
Sandusky Portland Cement Co., Sandusky, Ohio.
Newhouse, E. L., E.M., ... 1886.
Manager Philadelphia Smelting Company, Denver, Colo.
Newton, T. M., Ph.B., ... 1893.
40 West 75th Street, New York City.
Newman, M. L., E E., ... 1898.
107 East 90th Street, New York City.
Neyman, Percey, Ph.B., Ph.D., ... 1881.
Chemist and Assistant Superintendent, 36 Michigan Street, Cleveland, O.

Nicholas, Harry Parmelee, E.M., ... 1887.
Hotel St. George, 49 East Twelfth Street, New York City.
Noble, Charles Milton, E.M., ... 1879.
Manager Ruttan Manufacturing Co., Anniston, Ala.
Noble, Lewis S., E.M., ... 1885.
Address unknown.
Norris, D. H., E.M., ... 1877.
123 West Twenty-fourth Street, New York City.
O'Reardon, I., C.E., ... 1897.
229 East Eighteenth Street, New York City.
Oakes, J. C., B.S., Ph.B., ... 1893.
423 West Twenty-first Street, New York City.
Orner, G. D., E.E., ... 1899.
153 West 98th Street, New York City.
Oseranski, Isaac Henry, C.E., ... 1889.
Address unknown.
Otto, C. L., B.S., ... 1898.
885 Bushwick Avenue, Brooklyn, N. Y.
Owen, F. M., E.M., ... 1878.
115 East 45th Street, New York City.
Owens, Robert Bowie, E.E., ... 1892.
Professor Elect. Engineering, University of Nebraska, Lincoln, Neb.
Oxnard, James Guerrero, Ph.B., ... 1883.
Norfolk, Neb.
Painter, Robert K., E.M., ... 1896.
New York and Honduras Rosario Mining Co., San Juarisita, Rep. du Honduras, Central America.
Palmer, Cortlandt Edward, E.M., ... 1879.
Colorado Springs, Colo.
Palmer, George A., C.E., ... 1896.
922 Fifth Avenue, New York City.
Parmly, Charles Howard, B.S., E.E., ... 1892.
344 West 29th Street, New York City.
Parsons, George H., E.M., ... 1868.
Colorado Springs, Colo.
Parsons, H. A., C.E., ... 1894.
Stamford, Conn.
Pazos, Vincent Felix, E.M., ... 1878.
Address unknown.
Pearis, C. F., E.M., ... 1884.
Box 374, Helena, Mont.
Pearce, R., Ph.D., ... 1890.
Address unknown.
Peck, T. B., Jr., E.E., ... 1898.
111 East Thirty-fourth Street, New York City.
Pederson, F. M., B.S., E.E., ... 1893.
327 West Thirty-fourth Street, New York City.
Pelton, H. C., Ph.B., ... 1890.
No. 1 Mansion Avenue, New York City.
Penoff, Joel, C.E., ... 1896.
244 East Broadway, New York City.

Perry, Charles L., E.E., ... 1896.
14 Hampden Street, New York City.

Perry, Nelson W., E.M., ... 1878.
Editorial Staff "Electrical World," New York City.

Pfister, Philip Charles, E.M., ... 1875.
Address unknown.

Pierce, Harry Nelson, E.M., ... 1885.
Address unknown.

Platt, Charles Slason, E.M., ... 1868.
Assayer, 21 and 31 Gold Street, New York City.

Pomeroy, W. A., E.M., ... 1893.
Oswego, Oregon.

Pope, J. R., Ph.B., ... 1894.
111 East Twenty-fifth Street, New York City.

Portuondo, José, C.E., ... 1890.
Address unknown.

Post, A. Van Zo, C.E., ... 1889.
45 Wall Street, New York City.

Post, R. B., Ph.B., ... 1893.
Elizabeth, N. J.

Post, William Stone, Ph.B., ... 1890.
Bernardsville, N. J.

Potter, William B., A.B., E.M., ... 1883.
1225 Spruce Street, St. Louis, Mo.

Powers, Cornelius Van Vorst, Ph.B., ... 1882.
Assistant Engineer Aqueduct, Katonah, N. Y.

Primelles, José Alejandro, C.E., ... 1887.
Mercedes 23, Puerto Principe, Cuba.

Prince, A. D., C.E., ... 1893.
30 West Forty-seventh Street, New York City.

Proctor, William Ross, E.M., ... 1884.
43 and 45 Sixth Avenue, Pittsburg, Pa.

Provost, F. A., C.E., ... 1893.
Jerome, Arizona.

Provost, George, Ph.B., ... 1889.
Architect, 24 Highland Terrace, Orange, N. J.

Radford, William Helsham, E.M., ... 1877.
Lydenburgh Gold Mining Co., Limited, Manchester, Eng.

Raisman, A. F., C.E., ... 1898.
50 Wallace Street, Newark, N. J.

Ralph, H. P., C.E., ... 1897.
2305 Munroe Avenue, New York City.

Randolph, Edmund, Ph.B., ... 1883.
E. & C. Randolph, 7 Nassau Street, New York City, also Knickerbocker Club.

Rappold, G. W., Ph.B., ... 1897.
750 Flushing Avenue, Brooklyn, N. Y.

Raymer, George Sharp, A.B., E.M., ... 1881.
Mine Superintendent, Idaho Springs, Colorado, and 63 Seventh Avenue, Brooklyn, N. Y.

Raymond, Alfred, Ph.B. . . . . 1891.
123 Henry Street, Brooklyn, N. Y.

Raymond, Max, C.E., ... 1898.
166 Henry Street, New York City.
Raymond, Wm. O., Ph.B., ... 1896.
31 East Eighty-second Street, New York City.
Raynor, R., Ph.B., ... 1889.
114 East Forty-fifth Street, New York City.
Reed, William Bell Stephen, E.M., ... 1879.
Helena, Mont.
Rees, B. F., E.M., ... 1874.
Chattanooga, Tenn.
Reese, William W., A.B., E.E., ... 1892.
New Hamburg, N. Y.
Regan, George W., E.E., ... 1896.
352 Degraw Street, Brooklyn, N. Y.
Rennard, John C., E.E., ... 1894.
302 West Seventy-third Street, New York City.
Restrepo, C. C., E.M., C.E., ... 1887.
Medellin, Rep. of Col., South America.
Reyna, J. E., E.E., ... 1898.
The Elmer, Morningside Avenue, New York City.
Reynolds, M., A.B., Ph.B., ... 1893.
98 Columbia Street, Albany, N. Y.
Riederer, E. J., Ph.B., ... 1897.
145 West Ninty-fourth Street, New York City.
Richardson, J. C., E.M., C.E., ... 1883.
Address unknown.
Richmond, William Thomas, Ph.B., ... 1881.
68 Thomas Street, New York City.
Ridsdale, T. W., E.M., ... 1883.
39 Cortlandt Street, New York City.
Riedel, A. E., M.E., ... 1896.
146 Delancey Street, New York City.
Riggs, Geo. Washington, Ph.B., ... 1871.
Summit, N. J.
Riter, L. E., Jr., E.M., ... 1899.
2051 Seventh Avenue, New York City.
Rittenhouse, Charles T., E.E , ... 1894.
247 West 138th Street, New York City.
Roberts, Arthur Carr, E.M., ... 1881.
Address unknown.
Robertson, Kenneth, E.M., ... 1868.
General Manager West Superior Iron and Steel Co., West Superior, Wis.
Robertson, Richard Spotswood, Jr., E.M., ... 1871.
Jackson, Minn.
Robinson, F. G., E.E., ... 1893.
Superintendent Amsterdam Street Railway, Amsterdam, N. Y.
Robinson, Henry Alwood, Ph.B., ... 1880.
Lawyer, 150 Broadway, New York City.
Rogers, A. P., Ph.B., C.E., ... 1898.
305 West 55th Street, New York City.

Rogers, Charles Louis, E.M., C.E., ... 1877.
823 Broad Street, Chattanooga, Tenn.

Rood, R. G., Ph.B., ... 1884.
Care Professor O. N. Rood, Columbia University, New York City.

Ropes, W., ... 1899.
Care of J. B. Holder, Maine and Blake Streets, Lewiston, Me.

Ross, William Coleman, C.E., E.M., ... 1876.
Address unknown.

Rutherford, Lewis Hopkins, E.M., ... 1887.
Franklin, Pa.

Sanders, Wilbur Edgerton, E.M., ... 1885.
Mine Supt., Ewing and Seventh Avenue, Helena, Mont.

Sands, F., A.B., Ph.B., ... 1882.
Box 1172, Butte, Mont.

Savage, Seward Merrill, C. E., ... 1892.
2260 Pacific Street, Brooklyn, N. Y.

Sawyer, Charles Pike, Ph.B., ... 1881.
Sporting Editor *Evening Post*, New York City.

Sayers, J. H., C.E., ... 1897.
456 Classon Avenue, Brooklyn, N. Y.

Schlecht, W. W., C.E., ... 1897.
446 East 57th Street, New York City.

Schroeder, H., E.E., ... 1899.
137 Madison Avenue, New York City.

Schroter, G. A., E.M., ... 1893.
Box 877, Denver, Colo.

Schulte, E. B. N., E.E., ... 1899.
47 West 25th Street, New York City.

Seligman, J. G., E.M., ... 1887.
506 West 143d Street, New York City.

Sergeant, E. M., E.E., ... 1896.
Summit, N. J.

Serber, David C., C.E., ... 1896.
271 East Broadway, New York City.

Shack, Albert P., E.M., ... 1868.
108 East 25th Street, New York City.

Shire, Edward I., Ph.B., ... 1896.
109 East 61st Street, New York City.

Shope, Henry Brengle, Ph.B., ... 1885.
19 West 32d Street, New York City.

Shrady, Chas. D., ... 1895.
Continental Match Co., Passaic, N. J., and
8 East 66th Street, New York City.

Simonson, L. M., C.E., ... 1899.
Pelham, N. Y.

Skidmore, Samuel Tredwell, A.B., Ph.B., ... 1889.
71 West 50th Street, New York City.

Sclichter, W. I., E.E., ... 1896.
127 West 58th Street, New York City.

Sloane, Thomas O'Connor, A.B., A.M., E.M., Ph.D., ... 1872.
South Orange, N. J.

Small, Franklin Maurice, Ph.B., ... 1889.
Architect, 199 Second Avenue, New York City.

Smeaton, William Henry, C.E., E.M., ... 1877.
15 Horatio Street, New York City.

Smedberg, Henry Ashton, A.B., C.E., ... 1884.
347 Fifth Avenue, New York City.

Smith, H. A., Ph.B., ... 1893.
460 West 44th Street, New York City.

Smith, Maxwell, C.E., ... 1880.
Adon Smith, 8 Bridge Street, New York City.

Smith, O. B., Jr., Ph.B., ... 1897.
Morristown, N. J.

Smyth, Roland Mulvill, E.M., C.E., ... 1877.
452 Produce Exchange, New York City. 1879 to date, banker and broker.

Speyers, Clarence Livington, Ph.B., ... 1884.
Associate Professor Chemistry, Rutgers College, New Brunswick, N. J.

Stallnecht, Frederick, E.M., ... 1868.
Editor, 11 Bond Street, New York City.

Stander, Isaac, C.E., ... 1897.
315 East 77th Street, New York City.

Staunton, J. A., Jr., ... 1887.
Care Rev. John A. Staunton, 5 Seymour Street, Syracuse, N. Y.

Starr, Henry Fowler, Ph.B., ... 1879.
91 Mt. Pleasant Avenue, Newark, N. J.

Steers, James Rich, Ph.B., ... 1890.
10 East 38th Street, New York City.

Stern, Henry, Ph.B., ... 1896.
230 East 69th Street, New York City.

Steinam, J. L., Ph.B., ... 1894.
19 Union Square and 31 West 95th Street, New York City.

Stevens, Alexander, C.E., ... 1887.
No. 1 Newark Street, Hoboken, N. J.

Stewart, Hunter, E.M., ... 1875.
Address unknown.

Stilwell, A. G., B.S., ... 1898.
164 St. John's Place, Brooklyn, N. Y.

St. John, Thomas Matthew, Met.Eng., ... 1890.
New York City.

Stoughton, Arthur Alexander, Ph.B., ... 1888.
1665 Washington, Avenue, New York City.

Stoughton, Charles William, C.E., ... 1889.
1665 Washington Avenue, New York City.

Stout, J. S., Jr., A.B., E.E., ... 1897.
35 East 67th Street, New York City.

Stratford, T. A., C.E., ... 1899.
132 Berkeley Place, Brooklyn, N. Y.

Stratton, Alex., E.E., ... 1894.
Address unknown.

Strieby, William, A.M., E.M., ... 1878.
Professor of Metallurgy and Assaying,
Colorado College, Colorado Springs, Colo.

Strout, William Allen, Ph.B., ... 1891.
366 Carlton Avenue, Brooklyn, N. Y.
Suydam, John Richard, Jr., E.M., ... 1879.
14 East 41st Street, New York City.
Tachan, Wm. G., Ph.B., ... 1896.
Louisville, Ky.
Taylor, A. S. G., Ph.B., ... 1897.
205 West 57th Street, New York City.
Temple, S. J., Ph.B., ... 1892.
Address unknown.
Tennille, George F., Ph.B., ... 1894.
The Southern Cotton Oil Co., Savannah, Ga.
Thomas, Franz Charles, Ph.B., ... 1891.
Address unknown.
Thomas, W. S., E.M., ... 1898.
417 West 117th Street, New York City.
Thompson, H. C., C.E., ... 1886.
Lorillard Place, New York City.
Thompson, Milton Strong, Ph.B., ... 1875.
Chemist, Newburyport, Mass.
Thompson, S. C., A.B., E.M., ... 1893.
Grass Valley, Nevada Co., Cal.
Thorne, William Lincoln, Ph.B., ... 1890.
63 High Street, Yonkers, N. Y.
Tibbals,, R. G., C.E., ... 1897.
148 Milton Street, Brooklyn, N. Y.
Tilden, G. C., C.E., ... 1876.
Reefton, New Zealand.
Tilghman, H. A., E.M., ... 1893.
Sansleto, Cal.
Toch, Max B., Ph.B , ... 1896.
34 West 92d Street, New York City.
Tompkins, E. D. V., C.E , ... 1896.
732 West End Avenue, New York City.
Tompkins, J. A., 2d, Ph.B., ... 1894.
Astor Court, 25 West 33d Street, New York City.
Totten, George Oakley, Jr., Ph.B. (1892),. . . . . 1891.
62 North 11th Street, Newark, N. J.
Toucey, Donald Butler, LL.B., E M., ... 1882.
743 Madison Avenue, New York City.
Towart, James, C.E., ... 1892.
Box 296, Peekskill, N. Y.
Tower, A. E., E.M., ... 1883.
Poughkeepsie, N. Y.
Trapote, P., ... 1898.
130 West 29th Street, New York City.
Trowbridge, Samuel Breck Parkman, A.B., Ph.B., ... 1886.
Architect, 7 East 46th Street, New York City.
Tudor, W. J., A.B., E M., ... 1898.
240 West 121st Street, New York City.

Tubby, J. T., Jr., Ph.B., ... 1896.
67 Willow Street, Brooklyn, N. Y.
Tucker, Allen, Ph.B., ... 1888.
80 Washington Square E., New York City.
Tucker, John Henry, Ph.B., Ph.D., ... 1875.
Globe Smelting and Refining Company, Denver, Col.
Tuttle, W., Ph.B., ... 1893.
520 Summer Avenue, Newark, N. J.
Tuttle, William W., E.M., ... 1867.
Springfield, Mo.
Uhling, William C., Ph.B., ... 1896.
229 East 12th Street, New York City.
Value, B. R., E.M., ... 1884.
Address unknown.
Van Benthuysen, Boyd, Ph.B., ... 1896
Albany, N. Y.
Van Blarcom, E. C., C.E., ... 1876.
Hidalgo, Mexico.
Van Boskerck, Robert Ward, E.M., ... 1877.
Artist, 58 West 57th Street, New York City.
Van Brunt, Arthur Hoffman, Ph.B., ... 1886.
Architect, 57 Wall Street, New York City.
Van Dyck, Edwin, Ph.B., ... 1888.
1080 Dean Street, Brooklyn, N. Y.
Van Ingen, Dudley Arthur, Ph.B., ... 1892.
135 Henry Street, Brooklyn, N. Y.
Van Lennep, David, E.M., ... 1868.
Auburn, Placer County, Cal. Fruit ranch.
Van Vlech, Joseph, Jr., Ph.B., ... 1896.
Montclair, N. J.
Van Wagenen, H., Jr., B.S., ... 1899.
36 East 53d Street, New York City.
Van Wagenen, T. F., E.M., ... 1870.
1508 Filmore Street, Denver, Col.
Vanderbilt, W. D., C.E., ... 1894.
39 Monroe Place, Brooklyn, N. Y.
Vatable, J. J., Ph.B., ... 1894.
111 5th Avenue, New York City.
Volckening, G. J., Met.E., E.M., ... 1888.
315 Quincy Street, Brooklyn, N. Y.
Wainwright, Richard Tighe, C.E., ... 1890.
Rye, N. Y.
Wagner, Otto, E.M., ... 1898.
63 East 72d Street, New York City.
Waldenberger, C. A., Ph.B., ... 1897.
155 East 37th Street, New York City.
Wallace, William J., Ph.B., ... 1886.
Whitestone, N. Y.
Wallbridge, Frederick Kidder, E.M., ... 1884.
37 Ninth Avenue, Brooklyn, N. Y.

Walker, Joseph, Jr., C.E., ... 1880.
112 East 37th Street, New York City.

Wanier, Albert George, Ph.D., ... 1882.
Kreisherville, Staten Island, N. Y.

Ward, Norbert Reillieux, E.M., ... 1882.
Morgan Furn. Co , 1180 Broadway, New York City.

Ware, F. B., Ph.B., ... 1894.
3 West 29th Street, New York City.

Warren, Charles Peck, Ph.B., A.M. (1892), ... 1890.
386 Clinton Place, Brooklyn, N. Y.

Warren, Lloyd, Ph.B., ... 1891.
520 Fifth Avenue, New York City.

Waterbury, Cornelius Reed, C.L., C.E., LL.B., ... 1877.
Lawyer, 45 Broadway, New York City.

Wafers, George Safford, Ph.B., ... 1889.
Architect, Andrews, Waters & Sherwin, 42 W. Forty-third St., N. Y. City.

Webb, Henry Walter, E.M., LL.B., ... 1873.
Third Vice-President, N. Y. C. & H. R. R. R., and 15 West Forty-seventh Street, New York City.

Wedekind, E. H., Ph.B., ... 1888.
Spokane, Wash.

Weinstein, M. C.E., ... 1899.
544 West Forty-second Street, New York City.

Wells, D. C., E.E., A.B., ... 1896.
109 Willow Street, Brooklyn, N. Y.

Wels, Paul O., E.M., B.S., ... 1887.
Boston & Montana Co., Great Falls, Mont.

Welsh, Howard Farrington, E.M., ... 1890.
Mingo Mountain Coal and Coke Company, Hartranft, Tenn.

Werner, Henry Clay, Ph.B., ... 1892.
120 E. Sixty-fifth Street, New York City.

Wertheimer, Lewis, Ph.B., ... 1887.
Allegheny City, Pa.

Wetmore, Edwin Atwater, E.M., ... 1875.
Iron Merchant, Marquette, Mich.

Wheatley, Joseph Yendes, C.E., ... 1886.
Cold Spring, N. Y.

White, Lazarus, C.E., ... 1897.
14 East 120th Street, New York City.

Whitman, Edmund Pineo, E.M., ... 1885.
Hillside Avenue, Englewood, N. J.

Williams, Frederick Harrison, E.M., ... 1874.
Riverside Iron Works, and 34 Virginia Street, Wheeling, W. V.

Williams, G. W., E.M., C.E., ... 1879.
323 Genesee Street, Utica, N. Y.

Wilson, Clarence Edgar, Ph.B., ... 1886.
Address unknown.

Windecker, Clifton Nicholas, C.E., ... 1892.
33 Sydney Place, Brooklyn, N. Y.

Windolph, A. P., Ph.B., ... 1892.
Address unknown.

Windreple, A. P., Ph.B., ... 1892.
Address unknown.

Witherel, Chas. S., Met.E., ... 1896.
Greenwich, Conn.

Wreff, H. H., C.E., ... 1898.
548 West 148th Street, New York City.

Wood, George E., E.M., Ph.B., ... 1884.
Architect, 63 William Street, New York City.

Woodruff, George W. L., Ph.B, E.E., ... 1896.
27 East 22d Street, New York City.

Wright, Albert Allen, A.M., Ph.B., ... 1875.
Professor of Geology and Natural History, Oberlin College, Oberlin, Ohio.

Wright, R. G., B.S., ... 1898.
352 West 115th Street, New York City.

LIST No. 4.

Contains the names of Members of the Alumni Association classified territorially by their professional address. Those not Members of the Association are not included by reason of the uncertainty as to address of such persons

(Revised to January, 1900.)

GEOGRAPHICAL SUMMARY.

Showing the Countries and States in which the Association is represented by members who reside therein, and the State or country in which they reside. The local address of members will be found in List No. 2, in which their names are arranged alphabetically.

UNITED STATES.

State or Territory.	No. of Members.	State or Territory.	No. of Members.
Alabama	2	Nevada	2
Arizona	2	New Jersey	37
California	9	New York	345
Colorado	14	North Carolina	2
Connecticut	4	Ohio	4
Delaware	1	Oregon	2
District of Columbia	8	Pennsylvania	22
Florida	2	Rhode Island	2
Illinois	9	South Carolina	1
Idaho	1	South Dakota	1
Indiana	2	Tennessee	3
Indian Territory	1	Texas	5
Kansas	1	Utah	5
Maryland	1	Vermont	1
Massachusetts	7	Washington	2
Michigan	5	West Virginia	1
Minnesota	1	Wisconsin	1
Missouri	7	Wyoming	2
Montana	8		
Total, United States			523

FOREIGN COUNTRIES.

State or Territory.	No. of Members.	State or Territory.	No. of Members.
Australia	1	Guatemala	1
Canada	7	Honduras	1
Cuba	5	Mexico	13
Eastern Siberia	1	Nicaragua	1
France	1	Oceanica	1
Germany	1	Peru	1
Great Britain (England)	2	South African Republic	5
Total, Foreign Countries			41

Total, United States	523
Total, Foreign Countries	41
Present Address Unknown	6
Total Membership	570

Alabama.

Stonehill.—C. S. Herzig.
Tucaloosa.—S. Friedman.

Arizona.

Congress.—W. F. Staunton.
Pearce.—G. F. Reckhart.

California.

Bodie.—R. G. Brown, N. B. Knox.
Grass Valley.—G. F. Sherman.
Palo Alto.—L. R. Lenox.
San Francisco.—E. F. Haas, D. E. Melliss, R. A. Parker, E. A. Wiltsee.
Selby.—E. N. Engelhardt.

Colorado.

Denver.—H. V. F. Furman, M. W. Iles, C. F. Lacombe, B. B. Lawrence, T. B. Stearns.
Durango.—E. J. H. Amy.
Leadville.—Geo. B. Lee, E. H. Messiter.
Pueblo.—F. P. Bayles, K. E. Eilers, R. D. Rhodes.
Rico.—L. H. Barnet.
Silverton.—M. B. Holt, C. W. Miller.

Connecticut.

Bridgeport.—F. I. Cairns.
Collinsville.—W. Hill.
Hartford.—H. A. Perkins.
Middletown.—H. C. Sherman.

Delaware.

Wilmington.—H. G. Haskell.

District of Columbia.

Washington.—E. C. Barnard, Marcus Benjamin, E. M. Douglas, A. W. Dow, F. W. Tower, W. H. Weed, B. Willis, H. M. Wilson.

Florida.

Key West.—C. E. Rodgers.
Tampa.—R. E. Slade.

Illinois.

Aurora.—W. H. Van Arsdale.
Carthage.—J. C. Ferris.
Chicago.—E. G. Barratt, Edward Gudeman, H. L. Hollis, S. B. Peck, F. B. F. Rhodes, G. S. Rice, L. Wampold.

Idaho.

Moscow.—E. Goodwin.

Indiana.

Elkhart.—E. L. Kurtz.
Lafayette.—E. M. Blake.

Indian Territory.

Hartshorn.—E. Ludlow.

Kansas.

Argentine.—A. S. Dwight.

Maryland.

Baltimore.—H. A. Prosser.

Massachusetts.

Boston.—I. N. Evans, C. R. Harte, W. W. Lighthipe.
Cambridge.—J. A. Noyes.
Holyoke.—L. J. Powers, Jr.
New Bedford.—N. Hathaway, W. F. Williams.

Michigan.

Atlantic Mine, Houghton Co.—F. McM. Stanton.
Houghton.—H. D. Conant, F. W. Denton, R. M. Edwards.

Minnesota.

Minneapolis.—W. R. Appleby.

Missouri.

Ashburn.—E. J. Riederer.
Carthage.—A. O. Ihlseng.
Columbia.—Thomas Nolan.
De Soto.—O. M. Munroe.
Flat River.—G. Sessinghaus.
St. Louis.—E. Starek, A. Thacher, H. A. Wheeler.

Montana.

Bozeman.—F. W. Traphagen.
Butte.—F. Klepetko, B. R. Putnam, F. Sands.
Helena.—H. M. Cole, J. R. Parks.
Smelter.—P. A. L. Mannheim, F. M. Smith.

Nevada.

Gold Creek.—Frank Hamilton.
Tecoma.—E. G. Tuttle.

New Jersey.

Ampère.—C. M. Lowther.
Boyonne.—C. P. Bleecker.
Closter.—Chas. H. Eckerson.
Dover.—F. A. Canfield.
Fort Lee.—C. G. Massa, L. F. Massa.
High Bridge.—O. C. Beck, C. LeBoutiller.
Jersey City.—W. F. Downs, Chas. Drasel, O. F. Pattberg, R. H. Vondy.

Madison.—J. P. Pennington.
Mauser.—H. Garlichs.
Morristown.—J. R. Brinley, J. F. Randolph, E. Waller.
New Brunswick.—A. H. Chester, W. Van B. Van Dyck.
Newark.—H. G. Atha, C. A. Colton, Jos. Lowenstein, E. Merz, H. M. Murphy, G. C. Stone, F. Vanderpoel, W. Weiner.
Orange.—John Seward.
Passaic.—E. W. Guiterman.
Paterson.—J. H. Clark.
Perth Amboy.—D. F. Haasis, A. L. Walker.
Princeton.—H. B. Cornwall.
Roselle.—C. H. Jouet.
Rustic.—A. P. Van Gelder.
Trenton.—J. H. Janeway.
Wattesing.—J. Muller.

New York.

Albany.—F. J. H. Merrill.
Bedford Park.—N. L. Britton.
Brooklyn.—R. L. Allen, G. W. Behrman, S. D. Benoliel, R. T. Betts, D. D. Book, E. P. Clark, F. D. Dodge, W. L. Dusenberry, L. G. Engle, E. P. Folger, S. A. Goldschmidt, D. J. Green, F. S. Hyde, J. S. Langthorn, F. C. A. Meisel, J. H. Merritt, W. M. Meserole, H. H. B. Meyer, J. Middleton, J. Nesmith, T. S. Perkins, F. E. Pierce, A. J. Provost, C. B. Rowland, G. Rowland, R. Seldner, W. W. Share, E. Skinner, G. C. Southard, G. A. Tibbals, S. G. Tibbals, H. A. Titcomb, W. L. Tyler, H. V. Walker, F. G. Weichmann.
Buffalo.—H. S. Kissam.
Cazenovia.—H. Burden, 2d.
Clinton.—C. H. Smyth, Jr.
Flatbush.—E. R. Von Nardroff.
Flushing.—A. M. Ryon.
Great Neck (L. I.).—F. S. Dickerson.
Irvington-on-Hudson.—G. H. Casamajor.
Ithaca.—H. Ries.
Jamaica.—R. D. Godley, Jr.
Laurel Hill.—W. C. Ferguson, H. K. Masters.
Lynbrook.—J. J. Koen.
New Brighton.—W. B. Johnstone.
New Rochelle.—L. P. De Luze.
New York City.—E. K. Adams, S. W. Andrews, W. C. Andrews, L. A. Ansbacher, A. Anthony, P. T. Austen, S. W. Balch, W. M. Baldwin, J. H. Banks, P. A. Bates, A. P. Baumann, G. A. Baxter, A. C. Beatty, Chas. A. Bechstein, W. L. Benedict, John Berger, George Berry, W. G. Berry, J. Binion, J. R. Bien, R. R. Bishop, A. Black, Francis Blossom, M. T. Bogert, O. Bodelsen, W. Boecklin, Jr., E.

C. Boerner, S. Bookman, R. E. Booraem, R. C. Boyd, H. D. Brewster, V. M. Buck, C. R. Buckley, A. L. Burns, W. G. Burns, Wm. H. Burr, W. P. Butler, John Cabot, Jr., A. Calman, E. P. Casey, K. L. Caswell, Chas. F. Chandler, J. P. Channing, E. D. Church, J. A. Church, C. M. Clark, Edmund Clark, G. H. Clark, T. R. Coffin, F. A. Cokefair, J. T. Conover, Fredk. Coykendall, S. H. Crampton, F. B. Croker, A. R. Cushman, E. H. Daly, H. G. Darwin, C. H. Davis, J. W. Davis, J. A. Deghuee, A. F. Delafield, C. Derleth, Jr., C. H. Detwiller, W. B. Devereux, C. F. Dolan, J. S. Douglas, D. Le R. Dresser, I. W. Drummond, E. L. Dufourcq, E. K. Dunham, G. S. Eastwick, W. G. Eberhardt, A. H. Elliott, W. Elliott, G. E. Fahys, P. Le R. Fearn, Geo. A. Ferguson, C. F. Ferrer, H. Feuchtwanger, Henry Fisher, W. Fisher, R. A. Fliess, R. G. Foster, P. W. Foster, A. E. Foyé, J. W. Frank, S. B. Gifford, A. C. Gildersleeve, C. B. Going, G. A. Goodell, John Gordon, E. H. Gould, C. E. Graff, L. P. Gratacap, A. D. Granger, J. L. Greenleaf, L. N. Gross, H. S. Hadden, L. F. Haffen, R. W. Hall, A. P. Hallock, A. W. Hankinson, R. C. Hanson, G. E. Harding, E. A. Harris, G. M. Haskell, O. B. Hébert, A. M. Heinsheimer, H. H. Hendricks, J. M. Hewlett, W. E. Hildreth, W. L. Hildburgh, E. H. Holden, A. Hollick, H. M. Howe, F. F. Hunt, L. D. Huntoon, F. R. Hutton, H. St. J. Hyde, O. Jackson, D. M. Jacobs, S. J. Jacobs, F. H. Jobbins, T. H. Joseph, A. N. Jung, J. C. Kastner, J. F. Kemp, F. W. Kinsey, Burdett Kipp, G. T. Kirby, W. B. Kunhardt, J. H. Ladew, J. Lahey, D. G. Leary, G. Leary, E. J. Lederle, A. R. Ledoux, E. J. Levine, A. L. Levy, E. W. Libaire, A. Leibmann, Henry Lipps, Jr., W. P. Little, A. R. Livingston, L. B. Longacre, E. G. Love, F. R. Lord, Max Lowenthal, Frank Ludham, Frank Lyman, L. McI. Luquer, T. T. P. Luquer, G. Lusk, R. S. McCaffery, J. B. McClelland, P C. McIlhiney, C. F. McKenna, Alex. R. McKim, R. A. McKim, H. S. MacKaye, Jas. Maclay, C. H. Machen, H. B. Machen, C. A. Macy, C. S. McLaughlin, A. S. Mahony, R. E. Mayer, A. J. Malukoff, H. C. Mannheim, L. Marie, E. W. Martin, L. T. Martin, J. A. Matthews, E. H. Miller, R. P. Miller, S. O. Miller, E. J. Moeller, J. T. Monell, R. A. Monks, M. R. Montenegro, M. L. Mora, D. E. Moran, W. F. Morgan, R. K. Mosley, A. J. Moses, P. R. Moses, Robert Mulford, George Müller, H. S. Munroe, C. E. Munsell, A. C. Nye, M. J. O'Connor, T. D. O'Connor, E. E. Olcott, Max Osterberg, A. McC. Parker, H. C. Parker, C. F. Parraga, Henry Parsons, W. B. Parsons, C. Q. Payne, Robert Peele, C. E. Pellew, C. P. Pengent, S. Berkins, Geo. Perrine, W. Pistor, L. Pitkin, H. H. Porter, Jr., A. S. Post, W. E. Preston, J. L. Prince, J. C. F. Randolph, S. A. Reed, J. K. Rees, G. Renault, J. M. Rich, P. de P. Ricketts, T. W. Ridsdale, Chas. Rodenburg, O. N. Rood, F. M. Rutherford, F. Ruttmann, E. E. Sage, G. C. Saunders, R. M. Schell,

F. A. Schermerhorn, W. J. Schieffelin, A. F. Schneider, J. L. Schroeder, C. H. Schumann, H. J. Scudder, C. D. Searle, J. G. Seligman, L. R. Shattuck, F. D. Sherman, H. T. Shiver, F. M. Simonds, R. E. Slaven, A. Smith, F. P. Smith, L. Smith, W. F. Smith, Jr., T. E. Smook, A. N. Spooner, J. H. Stewart, J. Struthers, W. H. Stuart, G. A. Suter, H. H. Sutro, J. L. Tatlock, J. B. Taylor, W. H. Titus, F. Townsend, G. F. D. Trask, G. R. Tuska, L. H. Vail, Wm. D. Vanderbilt, J. H. Van Amringe, H. Van Sinderen, E. Van Volkenburgh, Jr., W. Vredenburgh, Jr., H. T. Vulte, J. H. Wainwright, Wm. R. Ware, W. H. Weeks, A. McM. Welsh, J. S. C. Wells, William Y. Westervelt, R. D. White, T. G. White, Wm. S. White, H. P. Whitlock, J. T. Williams, C. A. Wittmack, I. H. Woolson, E. L. Young.

Niagara Falls.—E. Z. Burns.
Northport.—W. H. Ingersoll.
North River.—F. C. Hooper.
Nyack.—E. L. Ingram.
Ontario.—E. M. Parrot.
Orangeburg.—S. R. Bradley, Jr.
Pocantico.—O. L. Rogers.
Rhinebeck.—H. Pinkham.
Rochester.—H. P. Gillette.
Rondout.—Edward Coykendall.
Skineateilis.—F. M. Thomas.
Spuyten Duyvil.—E. M. Johnson, G. H. Johnson, I. B. Johnson.
Stirlengton.—Wm. C. Clark.
Syracuse.—H. P. Bellinger.
Tarrytown.—F. N. Holbrook.
Westchester.—T. H. Harrington.
West Nyack.—George M. Miller.
Whitestone.—D. W. Ward.
Yonkers.—W. D. Horne.

North Carolina.

Charlotte.—S. W. Cramer, G. B. Hanna.

Ohio.

Cincinnati.—David Forester, C. McK. Lewis.
Cleveland.—R. F. Jopling.
Marietta.—C. G. Slack.
New Straitsville.—I. S. Lydecker.

Oregon.

Portland.—A. L. Beebe, F. Powell.

Pennsylvania.

Allegheny City.—G. E. Painter.
Chambersburg.—T. J. Brereton.

McKeesport.—T. M. Hopke, T. Tonnele.
Meadville.—I. Menline.
New Boston.—J. E. Jones.
Osceola Mills.—G. McC. H. Good.
Philadelphia.—E. A. Congdon, R. Lahe, S. M. Lillie, Charles Piez, A. Rosenthal.
Pittsburg.—W. L. McConway, C. L. Miller, R. G. G. Moldehnke, G. S. Page, C. A. Painter, G. Singer, Jr., G. H. Singer.
Scranton.—J. T. Beard.
South Bethlehem.—A. L. Colby.
Wilkesbarre.—R. Van A. Norris.

Rhode Island.

Hårwick.—Geo. L. Bennett.
Providence.—Carl Barus.

South Carolina.

Oakley.—J. P. Carson.

South Dakota.

Lead.—A. J. Clark.

Tennessee.

Copperhill.—R. Adams.
Gallatin.—A. J. Lamb.
Knoxville.—C. Van Deventer.

Texas.

Eagle Pass.—W. Hollis.
El Paso.—J. J. Ormsbee, D. W. Rickhardt, W. A. Smith.
Shafter.—W. S. Noyes.

Utah.

Jensen.—A. G. Johnson.
Salt Lake City.—T. S. Mathis, L. E. Riter, Jr., R. H. Terhune, W. A. Wilson.

Vermont.

Burlington.—W. H. Freedman.

West Virginia.

Porter Falls.—J. A. Le Prince.

Wisconsin.

Hurley.—G. H. Abeel.

Washington.

Pullman.—W. S. Thyng.
Spokane.—J. L. Warner.

Wyoming.

Evanston.—W. Newbrough.
Larimie.—C. H. Fulton.

OUT OF THE UNITED STATES.

AFRICA.

South African Republic.

Johannesburg.—B. P. Carter, T. H. Teggett, R. M. Raymond, F. Roeser, F. M. Watson.

ASIA.

Eastern Siberia.

Vladivostock.—W. S. Davidson.

AUSTRALIA.

Kalgoorlie.—Ralph Nichols.

OCEANICA.

Island Celebes.

Gorontalo.—E. N. Van Cortlandt.

FRANCE.

Paris.—J. B. Cauldwell.

GERMANY.

Heidelberg.—P. Rupp.

GREAT BRITAIN.

London.—B. C. Hinman, C. M. Rolker.

NORTH AMERICA.

Canada.

Nelson, B. C.—S. S. Fowler, E. C. Holden.
Montreal.—C. E. Gudewill, J. B. Porter.
Sydney, Cape Breton.—C. A. Meissner.
Trail, B. C.—W. H. Aldridge.
Whitewater, B. C.—Charles Of.

SOUTH AMERICA.

Peru.

Casapalca.—A. W. Jenks.

CENTRAL AMERICA.

Cuba.

Cardenas.—D. L. Clark.
Cienfuegos.—J. P. Ros.
Guantanamo.—L. F. Chibas.
Mantanzas.—Y. Y. Polledo.
Santiago de Cuba.—J. S. Cox.

Guatemala.

Quezaltenang.—J. F. Hawley.

Honduras.

Tegucigalpa.—E. C. Fiallos.

Mexico.

Chihuahua.—T. S. Austin.
City of Mexico.—V. M. Braschi, J. A. Navarro.
Concepcion del Oro.—A. W. Lilliendahl, F. A. Lilliendahl.
Durango.—L. V. Emanuel.
Monterey.—E. Howe.
Montersey, N. L.—L. H. Norton.
Pueblo.—T. W. Osterheld.
Ramos.—R. B. Watson.
Sierra Mojada.—A. E. Swain.
San Jose.—E. D. Self.
Zacatecas.—R. Yrizar.

Nicaragua.

Greytown.—H. W. Durham.

Address Unknown.

W. H. Cooper.
Max Dobbins.
E. B. Gosling.
W. B. McKinlay.
John R. Marsh.
Lowe Whiting.

CONSTITUTION

OF THE

ALUMNI ASSOCIATION

OF THE

SCHOOLS OF SCIENCE OF COLUMBIA UNIVERSITY.

Incorporated May, 1886, as The Association of the Alumni of the School of Mines of Columbia College. Named changed 1889.

ARTICLE I.

NAME.

The name of this Association is The Alumni Association of the Schools of Science of Columbia University.

ARTICLE II.

OBJECT.

The object of this Association is to promote the professional welfare of its members, and to strengthen the bonds of professional and social fellowship among the Alumni of the Schools of Science of Columbia University.

ARTICLE III.

MEMBERS.

SEC. 1. The membership of this Association shall be: I. Active. II. Associate. III. Honorary.

SEC. 2. All persons who have obtained degrees under the Faculties of Applied or Pure Science are eligible to active membership in this Association.

SEC. 3. Persons who have completed special courses under the

Faculties of Applied and Pure Science of Columbia University are eligible to associate membership in this Association.

SEC. 4. Persons eminent in science who are or have been connected with any of the Schools of Science of Columbia University are eligible to honorary membership in this Association.

SEC. 5. All members shall be elected to the Association by the Board of Managers.

SEC. 6. Honorary and associate members shall have all the privileges of active members, except those of voting and holding office.

ARTICLE IV.

DUES.

SEC. 1. The annual dues of active and associate members of this Association shall be three dollars, payable in advance on the first day of October in each year. Honorary members shall not be required to pay dues.

SEC. 2. Any member not in arrears may become a life member, and be relieved from further payment of annual dues by the payment, at any one time, of fifty dollars.

SEC. 3. Members one year in arrears may, after due notification, be dropped from the role, by vote of the Board of Managers, and shall then forfeit their rights and privileges in the Association until all arrears are paid, or until reinstated by the Board.

SEC. 4. Only those members not in arrears shall be entitled to vote or hold office.

ARTICLE V.

OFFICERS AND MANAGERS.

SEC. 1. The officers of the Association shall be a President, a Vice-President, a Treasurer and a Secretary. These officers and eight managers, to be elected as hereinafter provided, shall constitute the Board of Managers.

SEC. 2. The President, Vice-President, Treasurer and Secretary shall hold office for one year, and are eligible for re-election. The Managers shall hold office for two years, and are not eligible for re-election until one year after the expiration of their terms.

ARTICLE VI.

ELECTION OF OFFICERS AND MEMBERS.

SEC. 1. Before the last day of June of each year the President shall appoint a committee of five active members to nominate for election by the Association a President, a Vice-President, a Treasurer and Secretary for the ensuing year, and four Managers to serve for the ensuing two years. The officers and managers must be residents of New York City and vicinity.

SEC. 2. The four managers shall be chosen with due regard to a representation of the Alumni of the Schools of Science upon the Board of Managers, and they shall be selected, one from each of the four groups into which the Board at a previous meeting in that year shall have divided in chronological order the classes which have graduated from the Schools of Science.

SEC. 3. The nominating Committee must send in the nominations to the Secretary no later than October 15th of each year and such nominations shall be distributed within three weeks to the active members in the form of letter ballots, which must be signed and forwarded to the Secretary, and opened and counted by tellers at the annual meeting of the Association.

SEC. 4. In addition to such regularly appointed committee, any other five members, not in arrears, may constitute themselves an independent nominating committee, and may present to the Secretary before November 1st the names of such candidates as they may select. All the names of such independent nominees shall be placed upon the ballot list, with nothing to distinguish them from the nominees of the regular committee.

ARTICLE VII.

THE BOARD OF MANAGERS.

SEC. 1. The Board of Managers shall have the management of the affairs, funds and property of the Association, and it shall be the duty of the Board to see that the purposes of the Association are carried out according to its Constitution and By-laws.

SEC. 2. The Board of Managers shall hold at least four regular meetings during each year, namely, in the months of January, May,

October and December. Other meetings shall be called by the President as may be required.

SEC. 3. The Board shall have power to fill any vacancy in its body by the election of an active member of the association from the group in which such vacancy occurs.

SEC. 4. A quorum shall consist of a majority of the whole Board.

ARTICLE VIII.

PRESIDENT.

It shall be the duty of the President to call and preside at all meetings of the Board of Managers of the Association; to appoint such standing and other committees of the Association as may be found necessary or convenient for the conduct of its work, and to perform such other duties as may devolve upon him by virtue of his office.

ARTICLE IX.

TREASURER.

It shall be the duty of the Treasurer to collect and have custody of all moneys and pay all bills of the Association, but no indebtedness shall be incurred unless approved by the Board of Managers. No bill shall be paid unless previously endorsed by the Secretary. The Treasurer shall present to the Board of Managers a written report upon the financial condition of the Association at the annual meeting in December. His accounts shall be audited by a committee of the Association appointed at the annual meeting.

ARTICLE X.

SECRETARY.

It shall be the duty of the Secretary to issue notices for all meetings of the Board of Managers and of the Association, to keep minutes of all meetings, to record names, addresses, and professional occupations of the Members, and to perform such other duties as may be assigned to him by the Board of Managers.

ARTICLE XI.

DELEGATES TO ALUMNI COUNCIL OF COLUMBIA UNIVERSITY.

The Association shall be represented in the Alumni Council of Columbia University by delegates appointed by the Board of Managers, under such conditions and in such manner as the said Board shall prescribe.

ARTICLE XII.

MEETINGS.

SEC. 1. The annual meeting of the Association shall be held in the last week of December in each year, unless otherwise ordered by the Board of Managers.

SEC. 2. Regular meetings of the Association for social intercourse, or for the discussion of subjects of general or of professional interest, shall be held in the city of New York at such time and place as may be directed by the Board of Managers.

SEC. 3. Upon the written request of not less than ten active members, the President shall call a special meeting of the Association, which request, as also the notice of any special meeting, shall state the object for which the meeting is called.

SEC. 4. A quorum shall consist of thirty active members of the Association.

ARTICLE XIII.

SUSPENSION OR EXPULSION.

Any member of the Association may be suspended or expelled for misconduct in his relations to this Association or in his profession of proof thereof in such manner as may be prescribed hereinafter by By-laws.

ARTICLE XIV.

All interest in the property of the Association of persons resigning or otherwise ceasing to be members shall vest in the Association.

ARTICLE XV.

AMENDMENTS.

Any amendment to the Constitution must first be submitted in writing to the Board of Managers, and must be approved by a vote of two-thirds of the whole Board before presentation to the Association. Due notice of any proposed amendment shall be sent by the Board of Managers to every active member of the Association at least one month previous to the meeting at which such amendment is to be voted upon. A three-fourths' vote of the members voting, in person or by letter ballot, shall be necessary for the adoption of such proposed amendment.

BY-LAWS.

I. Unless otherwise directed the Order of Business at any meeting of the Association and its Board of Managers shall be as follows:

1. Reading of minutes of preceding meetings and action thereupon.
2. Report of the Board of Managers.
3. Report of officers.
4. Reports of standing committees.
5. Reports of special committees.
6. Elections and announcement of elections.
7. Unfinished business.
8. New business.
9. Appointment of committees.
10. Adjournment.

II. The absence of any member of the Board of Managers from two consecutive meetings of the same, of which he shall have been regularly notified, shall be considered as a resignation on the part of such member, unless the Board shall excuse such absence. The vacancy thus created shall be filled as provided for in the Constitution.

III. The Standing Committees of the Board of Managers shall be as follows:

1. On School of Mines Quarterly.
2. On Badges.
3. On Meetings of the Association.

All such committees, shall at the expiration of their terms of office, present written reports to the Board of Managers.

IV. The official organ of this organization shall be the SCHOOL OF MINES QUARTERLY, which will be furnished to all active and associate members.

V. The Standing Committee on Meetings shall arrange for regular meetings of the Association in October and March of each year unless otherwise ordered by the Board of Managers.

VI. These By-Laws may be amended at any regular meeting of the Association, but only by a vote of two-thirds of those present, and provided that ten days' notice in writing of the proposed amendment shall have been given to the Board of Managers, and also that notice of the same shall have been given by the Secretary in the call for the meeting.

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Four hundred Students of Columbia School of Mines have been instructed in the Woodbridge School. Also a large number have been prepared for Massachusetts Institute of Technology, Stevens Institute, Sheffield Scientific School, Lawrence Scientific School, Troy Polytechnic Institute, Cornell University, and the Classical, Medical and Law Departments of Harvard, Yale, Columbia and Princeton.

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VOL. XXI. No. 3. APRIL, 1900.

THE

SCHOOL OF MINES QUARTERLY.

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CONTENTS:

Memorial—Professor Thomas Egleston. By Alfred J. Moses..... 197
Engineering Tests on Direct Current Electrical Machinery with Preliminary Tests on the Properties of Conductors. By George F. Sever 218
The Progress of Ore Dressing—III. By C. Blömeke..... 239
The Paradox of the Pantheon. By A. D. F Hamlin..... 261
Notes on the Ferrocyanide Titration of Zinc. By Edmund H. Miller and E. J. Hall..... 267
Memorial—Frederick Morgan Watson..... 273
Abstracts in Analytical Chemistry. By Elwyn Waller..... 277
Abstracts—Current Mining Cases..... 286
Alumni and University News..... 292
Book Reviews..... 293

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THE

SCHOOL OF MINES QUARTERLY.

VOL. XXI. APRIL, 1900. No. 3.

PROFESSOR THOMAS EGLESTON.

BY ALFRED J. MOSES.

Thomas Egleston, first professor of the School of Mines and founder of the School, died on Monday morning, January 15th, at his home, 35 West Washington Square, New York city, at the age of sixty-seven years.

Professor Egleston was born in New York city, December 9, 1832. He prepared for college under Dr. Dudley, of Northampton, entered Yale college and graduated from the classical department in the regular four year's course in 1854. In 1854–55 he was a student in the Yale Scientific School of Analytical Chemistry and is said to have acted as assistant to Prof. Benjamin Silliman, Jr., although as this does not appear upon the records, it was probably as a volunteer assistant.

Soon after this he went to Paris and attended the lectures on Chemistry and Geology given at the Jardin des Plantes, and later obtained governmental permission to take an eclectic course at the École des Mines. The late Francis L. Vinton, subsequently chosen as the first professor of Mining Engineering in the School of Mines, and Prof. Henry A. Ward, of Rochester, were fellow students, and from the latter the following details were obtained:

Professor Egleston attended the École des Mines "for two or three years between 1856 and 1859. We met *often* in our classes and in his room (Rue des Beaux Arts) and mine. He did not take a regular course but followed certain lectures only—notably those of Prof. de Senarmont on Mineralogy, of Elie de Beaumont on Geology and of Prof. Bayle on Palæontology. His specialties

from first to last, were Mineralogy (notably on the crystallographic side) and Mining. The late General Vinton was a classmate for, I should think, less than a year. Neither he nor Professor Egleston graduated, they took only an eclectic course, with government permission to attend lectures in given departments."

After the completion of his course he travelled extensively, studying and collecting. He returned to New York in 1861, and was placed in charge of the work of sorting, determining and arranging the specimens which had accumulated at the Smithsonian Institution from the numerous governmental exploring expeditions. From these he prepared a series for the Institution and with the duplicates inaugurated a system of international exchanges. In connection with this work he prepared a Check list and Catalogue of Minerals which was sent by the Institution in 1862 to all correspondents.

That the work was satisfactorily done is evidenced by the fact that for eight years after the starting of the School of Mines the undistributed duplicates and all later accessions of the Smithsonian Institution were forwarded to Professor Egleston under an arrangement "to select and label a perfect single series for the National Museum and to exchange the duplicate specimens in its interest." *

PROFESSOR EGLESTON AS FOUNDER OF THE SCHOOL OF MINES.

In March, 1863, Professor Egleston published a "Proposed Plan for a School of Mines and Metallurgy in New York city," in which in a few words he stated plainly the object of the School, the proposed course of instruction and the estimated cost of first equipment.

The little pamphlet of about 1500 words was timely and practical, for at that period there was no institution in America primarily devoted to scientific and practical instruction in mining and metallurgy. An organization entitled The American School of Mines had been incorporated about 1859 in New York State by some prominent men, including Peter Cooper, Charles M. Wheatley and Robert G. Rankin, for "The economic and scientific development of the wealth of the United States, the determination of its economic values, the *instruction in the art of practical mining and the analysis and composition of mineral products.*". It does not appear, however, to have developed into a working school.

* Report of Smithsonian Institution, 1872, p. 51.

Professor Egleston stated as the object of the proposed school, "to furnish to the student the means of acquiring a thorough scientific and practical knowledge of those branches of science which relate to mining and the working up of the mineral resources of this country, and to supply to those engaged in mining and metallurgical operations, persons competent to take charge of new or old works and conduct them on thoroughly scientific principles."

No definite entrance requirements were made but a three year's course was outlined almost exactly as followed during the first few years of the school. Especial stress was laid upon 'summer work' and upon accurate notes. "At the commencement of the following year the student will be required to show from reports of works visited that he not only understands the theoretical principles of the subjects treated, but also their practical application; a point which will be insisted on with great rigor."

"One day in each week will be devoted to the examination of the pupils and the inspection of their note books, which they will be required to keep with care."

The estimated expense of equipment was $17,300 of which over one-half was for collections.

Professor Egleston's idea appears to have been to graft the school upon some existing institution and he is said to have first submitted the plan to the Trustees of Cooper Union and then, fortunately, to the Trustees of Columbia College, who for several years had been considering the establishment of Schools for graduate work, among others "a School of Sciences,* in which shall be pursued Mechanics, Physics, Astronomy, Chemistry, Mineralogy, Geology, Palæontology, Engineering, Mining, Metallurgy, Arts of Design, History of Science, Natural History, Physical Geography."

The opportunity to make a first step in this direction seemed to exist in the plan of Professor Egleston, and the plan was referred to a committee of the trustees, who reported that while the organization as planned required a larger outlay than the financial condition of the college warranted, "the nucleus of such a school could be formed at inconsiderable cost to the college and so as to

* Prior to the School of Mines there had been a School of Chemistry at Columbia College. Their circular of 62–63, gives as officers Charles King, President, Charles A. Joy, Professor of Chemistry, Morris Perkins, Assistant in Analytical Chemistry. At that date there had been 32 graduates. The instruction was principally in laboratory work, with a little physics and mineralogy. No degree was conferred.

be capable of expansion whenever the means of the College shall permit." The Trustees thereupon set apart rooms in the college building for mineralogical and geological collections, appropriated $500 for fitting up cases and, February, 1864, appointed Thomas Egleston, Jr., Professor of Mineralogy and Metallurgy without salary.

Although no money was appropriated with which to buy collections, the small mineral collection of the College was placed at the disposal of the new school and Dr. Egleston obtained gifts from Mr. George T. Strong and the Hon. Gouverneur Kemble, by which two private collections of considerable value were secured. From these, before the opening of the School, he formed a very fair working collection of minerals and a smaller geological collection. Several gentlemen including Mr. George T. Strong, Dr. John Torrey and William E. Dodge, Jr., contributed $3,000 with which a small laboratory was equipped.

The first circular, 1863–64, gives as the officers only Chas. King, LL.D., President, and Thomas Egleston, Jr., A.M., Professor of Mineralogy and Metallury, while a later circular, containing an appeal for funds, says as to the officers and equipment, "For the establishment of this School, the College provides Professors and Lecturers of high reputation and ability in their respective departments. Its mineralogical and other collections, and its apparatus (which is believed to be the most extensive and complete in the country) will be made available."

On November 15th, 1864, the School opened in the basement of the old college building with fifteen students, which by the end of the month had risen to twenty-nine and later to forty-three. Professors Vinton and Chandler had been appointed and various officers of the College had volunteered their services, so that the list stood: F. A. P. Barnard, S.T.D., LL.D., *President;* Thomas Egleston, Jr., A.M., *Professor of Mineralogy and Metallurgy;* Francis L. Vinton, *Professor of Mining Engineering;* Charles F. Chandler, Ph.D., *Professor of Analytical Chemistry;* John Torrey, M.D., LL.D., *Lecturer on Botany;* Charles A. Joy, Ph.D., *Lecturer on Geology;** W. G. Peck, LL.D., *Lecturer on Mechanics and Mining Surveying;* Ogden N. Rood, A.M., *Lecturer on Physics;* John H. Van Amringe, A.M., *Lecturer on Mathematics.*

* Although so printed in the circular, Dr. Chandler states that Professor Joy gave instruction in General Chemistry and German, Professor Chandler in Analytical Chemistry, Assaying and Geology. *University Quarterly*, March, 1900, p. 141.

Mr. John A. Church, the twelfth student to register, sends the following account of the conditions which prevailed in these first years of the School of Mines.

"In the spring of 1864 I was preparing to go to Europe to study mining, but mentioning the matter to the late Professor Joy I was told that "a Mr. Egleston," of 10 Fifth Avenue, had proposed to found a mining school in connection with Columbia. I went to see the future professor of metallurgy who said that the school would be opened if they had twenty applications from students, and that I made the twelfth. The school did open in November with 29 students."

"Our first quarters were in some of the College cellars and in an old building which had been used, I believe, as a wall paper factory.* The equipment was very limited. Of course, it was possible to buy chemical apparatus, and when the assay room was established it was the most generously furnished in the country, though it would be called a small affair now. There was a furnace for every four students. Professor Egleston gave some minerals and by the generosity of a few gentlemen in New York other collections were added so that a fair working knowledge of the principal minerals could be had. Crystallography came later, and when Professor Albert H. Chester, now of Rutgers College, was Professor Egleston's assistant, one of his most absorbing occupations was the preparation of the "blocks" that have worried so many students. He marked them out and they were cut by an ingenious carpenter who was employed in making the mineral cases."

"The metallurgical collection was of slower growth and for several years contained little more than a few wooden models of antiquated furnaces. The mining department was in the same condition and it was not until I left the School that Dr. Chandler's cabinets illustrative of applied chemistry even began to take shape. The department of geology was by far the best furnished in its beginning, Dr. Newberry bringing a collection that was more complete than any of the others."

"The chemical laboratory was in one of the cellars, and instead of the separate tables which the students have now there was a broad shelf built around three sides of the cellar, with drawers and

* Described by Professor Newberry in an address to the Alumni, April 4, 1883, as "A handfull of students and a little rude apparatus, housed in an abandoned Broom actory—an appendage to the old Deaf and Dumb Asylum."

a closet under it for each student. Such a thing as a metallurgical laboratory was only dreamed of and I believe there was no drawing room the first year."

"Though the actual state of these necessary aids to study was not good, the collections were all planned on a great scale and as far as possible the work was done thoroughly. The assay laboratory was the best in the country, the crystal models for every day use more abundant and complete than in any other school in the world. The best design was sought in tables and cabinets and with all its shortcomings the new institution not only gave full promise of its present state of perfection, but was in fact in some particulars superior to any other existing at the time."

"Not the least of its advantages was the character and spirit of the students who came in its early years. Their preparation would be considered very inferior now. There had been no standard and therefore there was no uniformity. Some came from colleges and others from common schools or business. Some were civil engineers in full practice. These differences of preparation had less effect upon the character of the School than the uniformity of spirit in study and desire to learn the mysteries of the new and fascinating pursuit that lay before them. The earlier classes were filled with really eager students and though many causes combined to make the instruction they received in the first year irregular and imperfect, their honorable and useful activity in later professional life is evidence of the good beginning made."

"The relation between professor and student was very close. All the instruction came direct from the head of the department and even the laboratory work was mostly guided by him. This system has its advantages and no doubt the enthusiasm of the first students was traceable directly to this intimate association. In that day, however, it was not a system but an accident due to the extreme difficulty of finding assistants who had the necessary training. The burden on the professors was very heavy and could not have been borne if the School had offered the multiplicity of courses * which it has now."

---

* Nominally two courses were offered but they were nearly identical and all students took the mining course. The only *stated* difference in the circular of 1864–65 being "candidates for the degree of Mining Engineer will not be required to attend the lectures in Botany, and those for the degree of Bachelor of Science need not attend the lectures on Mining Engineering."

"Out of the 49 graduated in the three classes that were in the School with me (the course was covered in three years then), 24 have been engaged in mining or metallurgy, 7 in other professions, 11 in business, 4 were so favored by fortune that a business life was not necessary to them and the career of 3 is unknown to me; so 63 per cent. have followed some profession."

In 1865 the trustees definitely recognized the success of the experiment by formally organizing the School of Mines as a branch of Columbia College. In the circular of 1865–66, Professor Chandler appears as Dean of the Faculty and thereafter Professor Egleston's energies are more restricted to his own department.

Professor Egleston's Work in Mineralogy.

Professor Egleston throughout his active connection with Columbia remained at the head of two widely different subjects. His first love was undoubtedly mineralogy, and metallurgy he assumed unwillingly, because he could not persuade anyone else to undertake it. In his original estimate for equipping a School of Mines the items and the accompaning comment show the importance he assigned to mineralogy, though it is probable that under this he included ore deposits and lithology.

Collections of Minerals	$7000.00
Cases for Collections	3000.00
Metallurgical and Chemical Laboratories	3000.00
Library	2000.00
Mining Tools and Models of Machinery	2000.00
Metallurgical drawings	300.00
	$17,300.00

"In case it should not be thought advisable to carry out the whole plan at once, it will be best to commence by providing for the acquisition of a collection of minerals, and some arrangement should be made for the gradual purchase of a library on subjects relating to the sciences taught."

The courses in Mineralogy included courses in Crystallography and in Blowpipe Analysis; for these he prepared diagrams and tables in 1866 and 1867, and in 1871 printed his "Lectures in Mineralogy." From the outset the courses were practical, involving few lectures and a maximum time in laboratory work, conferences and

handling of specimens. Neatness and cleanliness were made very important factors, and in the conferences the students were rigorously drilled in compositions, systems and distinguishing characters.

The story of the creation of the present mineral collection of 30,000 specimens is one that can not easily be paralleled in collection-building. At no time has there been a separate fund for the purchase of minerals and at no time a curator. By far the greater number of specimens have been secured either by gift, not voluntary, but solicited, or by exchange for other specimens similarly obtained. The 30,000 specimens now in the museum represent the picked residue of at least 100,000 acquired and exchanged.

To quote a favorite expression of Professor Egleston "at the start it was the day of small things." The college had a small collection which had not been unpacked after the move from College Place until it was turned over to the new School. According to the catalogues it included about 2000 specimens purchased from Professor James Renwick, and about 1000 specimens collected by N. F. Moore, President of Columbia College from 1842 to 1849, and author of Moore's Ancient Mineralogy. Unfortunately at the time of moving from the College Place site the packing had been left to the janitor and the specimens and labels had been packed separately. As a natural result uncertainty existed as to localities, greatly lessening the value.

The first gift obtained for the new collection was in February, 1864, when Mr. George T. Strong presented the money to purchase the collection of Mr. Hale, of the *Commercial Advertiser*. The collection was rich in American species, especially from New York and Connecticut. In July, 1864, the Hon. Gouverneur Kemble gave $2000 to purchase a collection made for a Mr. Gilmore, of Baltimore, under the personal direction of the famous Abbe Haüy, and containing many autograph labels of Haüy and Brongniardt. A year later the Trustees authorized Professor Egleston "to perfect an arrangement between the School of Mines and the Smithsonian Institution by which the collections of the School received the benefit of the international system of exchanges administered by that institution." Under this arrangement, as previously stated, the duplicates and newly acquired specimens of the Smithsonian were sent to Professor Egleston, who first selected and labelled a perfect single series for the National Museum and then exchanged the duplicate specimens.

About 1866 Professor Egleston proposed to the Trustees to send a circular letter to foreign governments stating the fact of the organization of a School of Mines at New York, its possession of duplicate minerals and geological reports and its desire to enter into relations of friendly exchange. Such a letter was sent to all the governments of this Continent, South America and Europe, and favorable answers received from most of the governments of Europe. To those replying an offer was sent to furnish to the libraries in each country, where mining was a prominent industry, works relating to the Geology of the United States. A list was sent to be checked. The books called for were purchased and shipped and the University received in return valuable exchanges, in most instances sets of publications on Mining, such as the Annales des Mines, to the great benefit of the library of the School. In two instances, St. Petersburg and Clausthal, minerals were sent; the Russian suite being the more valuable and including the 24 oz. platinum nugget since twice stolen and recovered. The ship in which this suite was sent was wrecked on Fire Island and some of the minerals lost but replaced by others sent later.

During the next five years a large number of special gifts for the collection were obtained, including minerals from Mexico, Pennsylvania and Michigan, by W. E. Dodge; Saxon collections made by Messrs. Prime and Wayne; and the fine suite of English fluorites; the Sanitary Fair Exhibit of Stalactites, from Schulsberg, Wisconsin, purchased for the School by Mr. G. H. Almy.

In 1870 Professor Egleston collected money to the amount of $2546 from Messrs. Dodge, Aspinwall, Parrott, Jessup, Kemble and D. S. Egleston, and with it purchased missing varieties.

The remaining large donations to the collection were the Chesterfield Mass. minerals in 1879, by Messrs. Hoe, Pyne, Stuart, Hilton and DePeyster; the celebrated collection of Professor How, of Nova Scotia minerals, in 1880, by Messrs. A. H. and C. T. Barney; and finally Professor Egleston, in 1899, presented his own collection of some 7000 specimens. Hundreds of smaller gifts have been made, all of which are recorded and credited to the donors.

Taken all in all the building of the Mineral Collection ranks second only to the founding of the School of Mines in the services of Professor Egleston to Columbia. The recent action of the Trustees in attaching the name "Egleston Mineralogical Museum" to this collection is peculiarly appropriate, and the memory of Pro-

fessor Egleston could not be honored more suitably than by the creation of an endowment fund for the museum that he loved and that henceforth bears his name.

To insure a comprehensive view of this phase of Dr. Egleston's work, I have obtained letters from my predecessors Professor Albert H. Chester of Rutgers College, first assistant in Mineralogy, 1864–68, Professor Henry B. Cornwall, of Princeton, Assistant from 1868–73, and Professor Chas. A. Colton, Director of the Newark Technical School and assistant from 1873 to 1882. Professor Chester writes:

"Professor Egleston's most noticeable characteristics, when I first knew him, just at the time the School of Mines was opened, were his industry and his enthusiasm. He came six days in the week, reaching the College early and usually staying through the day. He very seldom took a day off that first year, his work being very engrossing. He was preparing and delivering new courses of lectures, organizing his own department, and helping and advising in the general organization of the School, and at the same time bringing into shape the numerous collections that had been acquired for the new School by gift and purchase. No one who sees the orderly arragement of the collections now can imagine the vast confusion that reigned then, a confusion much increased by the lack of suitable cases and exhibition room. The time of six men could have been profitably used in the work of the Department during these first years, but during some of the time I was Professor Egleston's sole assistant, and he never had more than one besides. Yet he never seemed discouraged and was always saying, "We shall finish the routine work soon and have all in order. Then we shall have time for original investigation." The routine work was not finished during the four years that I was with him."

"The making up of a collection of crystal models in wood, for use in teaching crystallography, was a great work and took up the time of nearly a whole college year. This set of models was by far the most complete that had been seen in this country up to that time, and was most admirably adapted for the purpose intended. Professor Egleston was most interested in the growth of this collection and was continually calling for the construction of additional forms, and bringing books from his library to help in the work. As new and seldom seen forms were made, he showed a keen delight in them and never seemed to tire of looking at them and talking about them.

His interest and enthusiasm were so great as to completely absorb him, and I recall those months as among the most pleasant during my years of intercourse with him. Our quarters were so constructed that we were thrown constantly together, but he was always genial and pleasant even under some most trying circumstances."

"I was so fortunate as to be a member of the party that he led in 1866, to explore the first one hundred miles of the Union Pacific Railroad. In this he showed his ability as an organizer and director of such work, and though he did not often camp with us, he was with us enough to exhibit to all those qualities for which we shall never cease to love and respect him. He was ever ready to take his part in the necessary camp work when in camp, and one of the most vivid pictures I have of him is one where he is vigorously driving tent pegs with a heavy mineral hammer. Camping with a man is a great test of his qualities, good and bad, and we found him all that we could have asked as leader, instructor and friend."

Professor Cornwall writes: "In the year 1863–64 Professor Joy's laboratory for optional students in chemistry was very full, and four of us were working in a little side room in the chemical department of the old Deaf and Dumb Asylum building. One afternoon Professor Joy came through our room, accompanied by a gentleman who to my fancy had somewhat of a foreign air, and who appeared much interested in all he saw; observing everything closely and asking questions in a nervous, decided way, as if anxious to get an accurate idea of what was going on. That was my first acquaintance with Professor Egleston, and he was then on a visit to examine the mineral collection of the college. The next fall, in 1864, I returned to the college as assistant to Professor Joy, and the first year, 1864–65, of the School of Mines had already begun. I only met Professor Egleston as a student, as I had entered for the degree of E.M., but I heard of nights spent, well beyond midnight, in preparing the lectures he had no other time to prepare; minerals seemed to gather by magic and soon the few floor cases and wall cases showed a goodly array of really excellent specimens; and there was an atmosphere of work such as the old college had not seen before.

In the summer of 1865 Professor Egleston spent several weeks with a party of four students surveying some mining property in

Sullivan county, New York. The professor was indefatigable, climbing hills, going deepest into old diggings, and setting us all at work overhauling a dump heap at the old Ellenville lead mine, searching for brookite crystals on the quartz groups. In 1866 I went to Europe and returning in '68 I found the School much more comfortably fixed in a building that had replaced the Factory. I finished my work for my degree that winter, spending the next spring in arranging and labelling the mineral collection, and next fall (1868–69) I became Professor Egleston's assistant. I then best understood what a worker he was. From ten o'clock until four, nearly every day, he was there; and something was going on all the time. New minerals, new metallurgical specimens; proofs of his book on mineralogy; conferences with his colleagues; apparatus to be tested, altered, improved—always something to be done. The classes began to increase; the course in blowpipe analysis was elaborated; German methods and instruments were introduced, the results of a visit to Freiberg and a course taken by the Professor himself under Professor Richter, in blowpipe analysis. Already the students had learned that the Professor expected them to work, as well as himself. He was always fair in his methods of examination, but the student must come up to the mark, and that meant a good deal of work, for Professor Egleston was a rapid lecturer and covered a great deal of ground."

"Nor was the practical side the only one that attracted him. A great deal of energy was spent on what I know, his colleagues considered the too theoretical side of mineralogy. He gathered apparatus for optical mineralogy, and although, he did not lecture on it during my time, yet he had mechanics and opticians busy much of the time in devising new arrangements of apparatus which it was evident he hoped some time to bring into use. The result of his initiatory work is, perhaps, now best seen in the fine equipment at Columbia for just this sort of study. His mind was too active to be satisfied with the purely practical, although he know as well as anyone how to value practical results. In the spring of 1873 his health gave out, and he was forced to go to Europe, leaving his whole work at the School, lectures as well as laboratory practice, in the hands of myself and another assistant."

While Professor Egleston was deeply gratified at the growth of the School, I think he was never quite so happy in it as

during the first eight years, when he could keep oversight of everything in his extended department; for he dearly loved to know each specimen and see just where it went. Perhaps he always succeeded in doing so, but be spoke to me once of those years as "halcyon days," and I think he felt not only the infirmities of his health, but the impossibility of maintaining the close personal contact with all his students quite as much as any other member of the faculty, although sometimes his manner seemed indifferent. He was impatient, too, of restraints that resulted from the increasing numbers of the faculty, and this not from any personal feeling, but because he felt, I believe, that only those who, like himself had been through all the early days of struggle could have the same absorbing interest in the work that he felt."

Professor Colton writes: "There was a certain minute attention to detail which Professor Egleston insisted upon that was beneficial to anyone. His enthusiasm was also an incentive to those associated with him, and while at times this would reach almost a white heat and be suddenly dissipated, still there was an undercurrent which his assistants were bound to imbibe if they were at all sympathetic and interested."

"At the time of my appointment as assistant to Professor Egleston, the mineralogical collection was in a room over the qualitative chemical laboratory and numbered about 5000 specimens. This room also contained a part of the metallurgical collection Immediately above this was the blowpipe laboratory, Professor Egleston's private office and laboratory. In the garret over these was the storeroom for duplicate specimens."

"When the old Fiftieth Street building was torn down the collection was moved to the old college building and chapel and upon completion of the new building the department of Mineralogy and Metallurgy was assigned to the former "drawing room" in the old wall-paper factory on Fourth Avenue. The collections had by this time grown to such an extent that it became necessary to increase the case capacity nearly twice, and in the new quarters the blowpipe laboratory occupied the Fiftieth Street corner of the building, the collections were in the old drawing room, and Professor Egleston's private office and laboratories occupied a new building erected at the south end extending nearly to the corner of Forty-ninth Street."

"With the growth of the School came another demand for more

space, and a second time during my connection with Professor Egleston, the collections had to be moved to temporary quarters. Before the new building on Fourth Avenue was completed, my connection with School of Mines ceased."

To the very end Professor Egleston retained his interest in the mineral collection. The year of his retirement when only able to work over the cases a short time at once he insisted upon himself selecting and inserting the new specimens, and only a few months before his death he gave to the collection specimens obtained by him in the summer of 1899.

Professor Egleston's Work in Metallurgy.

In metallurgy the method of instruction adopted and followed to the end was by lecture. As before stated, Professor Egleston would at the start have preferred to relinquish metallurgy to some one else, and is said to have proposed this to a well known mining engineer of this city.

Having however undertaken the subject he gave his usual conscientious and tireless attention to the collection of material for his lectures, preferring always original sources of information and travelling every year in the country or in Europe always returning with a new mass of data for lectures and for descriptive articles.

His first publication in metallurgy was his Metallurgical Tables published in 1868, 1869 of which Mr. John A. Church says: "He published for the convenience of his students a compendium of the tables used in his lectures, an unpretending work, but one that would be extremely useful to the smelter if it could be modernized and kept up to date. The book, has the fault of attempting uniformity in describing the results of an art that is unconquerably diverse, but there is a mass of details given by which the pretensions of inventors can sometimes be checked or actual progress in economy ascertained."

His lectures were delivered with great rapidity and with an almost overwhelming mass of detail. In spite of this he required *and obtained* from the students a very full and exact knowledge of the subject treated. The thumbed and worn appearance of the books in the library which contain his articles speak eloquently of this. For the practical application of the principles taught he devised the "Metallurgical Project" and his conscientious attention

to detail is well illustrated in a personal letter which he used to send to each student outlining this work. For example, take the following from an old letter book, the handwriting that of Professor Egleston:

JULY 1, 1865.

MR. ———.

For your journal of travel for 1865 you will visit the coal mines and iron furnaces and rolling mills about Scranton, Luzerne Co., Pa., and examine the coal fields as far as Wilkesbarre. You will then go to Mauch Chunk and examine the coal fields of that district. At Bethlehem, Pa., you will find zinc works and at Catasauqua and Hokendauqua, large iron works.

You will find in Jersey City, iron, steel and zinc works and machine shops most of which are worth visiting.

At Chicopee near Springfield you will visit the works of the Ames M'f'g Co. and report upon the manufacture of brass and brass cannon and also the different methods of making iron castings.

At East Hampton you will examine the lead mine and endeavor to obtain suites of its minerals for the School.

Yours respectfully,

THOS. EGLESTON, JR.

PROFESSOR OF MINERALOGY AND METALLURGY.

The almost complete passing into metallurgy was coincident with and in a measure caused by the founding of the American Institute of Mining Engineers in 1871. Professor Egleston was approved for membership at the first meeting and thereafter for over twenty years was one of the most vigorous members, twice a manager, three times vice-president, and in 1887, President. He contributed to their transactions over thirty articles, and in this period published in all nearly one hundred books and papers on metallurgical subjects covering a wide field and to a very great extent the result of data collected either in his extended tours in the west in 1874, 1887, 1888 and 1889, or in the almost yearly trips to Europe. In some of the articles laboratory investigation played the principal part.

Professor J. K. Rees who with two other students accompanied Professor Egleston in 1874, thus describes the collecting of the data for the description of the Boston and Colorado Works at Black Hawk, Col.:

"We made hundreds of sketches and took thousands of measurements of all the machinery, apparatus and furnaces, while Professor Egleston obtained from Dr. Pearce, the Superintendent, a detailed description of the processes used in the works. Nothing seemed to escape his attention and when we left Black Hawk he had a large volume of notes."

Over twenty of the articles were published in the SCHOOL OF MINES QUARTERLY and others by the Society of Civil Engineers, or Society of Mechanical Engineers and a long series in London Engineering became later the basis of his most ambitious work, the Metallurgy of Silver, Gold and Mercury in the United States, in two large volumes in 1887 and 1890.

Professor Egleston was one of the organizers of the American Institute of Electrical Engineers, the Society of Mechanical Engineers and the American Metrological Society, and a member of the Society of Civil Engineers, the Iron and Steel Institute of Great Britain, the New York Academy of Sciences, the Century Club and various other societies. As a member of the Committee on Standardization appointed by the American Society of Civil Engineers, he favored a millimeter wire gauge standard, in opposition to the other members who favored a scale in thousands of an inch.

In 1866 he made an agricultural and geological survey of the first hundred miles of the Union Pacific Railroad. In 1868 he was United States Commissioner to examine the fortifications of the coast. In 1873 he was a juror at the Vienna Exposition.

Aside from his scientific work Professor Egleston gave a great deal of attention to church and charitable work. He was a Vestryman of Trinity Church from 1878 to 1898. At the time of his death he was Junior Warden and member of the Committees on Parish Work, Parish Schools and Cemetery. For nearly thirty years he was Vice-President of the Protestant Episcopal City Mission Society and for some years a trustee of the General Theological Seminary. He also first introduced the "Diet Kitchens" for the poor in New York.

To Professor Egleston is also due the credit for the formation of the Public Parks Protective Association which at the time of the Tweed ring opposed successfully the destruction of Washington Square, and in 1887 when the grave of John James Audubon was in peril from the opening of 153d Street to the river, he prevailed

upon the trustees of the cemetery to grant a plot in a better location, on condition that a handsome monument be erected by national subscription, and served as chairman of the committee which raised the money.

In 1874 the degrees of Ph.D. and LL.D. were conferred upon Professor Egleston by Princeton and Trinity respectively. On February 6, 1890, he was appointed a Chevalier of the Legion of Honor upon recommendation of the Director and members of the Faculty of the École des Mines, "in recognition of distinguished services to Science and to the École des Mines." In 1895 he became Officier and in his honor the Trustees of Columbia University, on February 5, 1900, named the museum attached to the Department of Mineralogy, the "Egleston Mineralogical Museum," thus permanently connecting his name with the collection which he created and loved.

In 1894 his health failed and in 1896 a second severe illness prostrated him. Upon his return he endeavored to resume his lectures, but the effort was too great and he requested to be retired. He was made Professor Emeritus, June 30, 1897, and thereafter when his health permitted, devoted himself to preparing biographies of two of his ancestors. Though nearly to the last he spoke of again taking up scientific work, he evidently had little hope, and in 1898 began disposing of his library and collections, giving nearly one thousand books to different departments of Columbia, his machinery and tools to the Department of Metallurgy and his mineral collection to the Department of Mineralogy, saying that he preferred to send them while he lived rather than leave the task to his executors.

The story of Professor Egleston is that of a man of wonderful energy and unceasing activity who in science strove hard to cover a field far too large for any one man, yet who did much therein that was of great service, not chiefly as an original investigator, but more as a diligent observer and recorder both here and abroad, with a keen sense of what was new or likely to prove valuable. In this connection Dr. R. W. Raymond, long his colleague, writes:

"His numerous contributions to the Transactions of that society (*Am. Inst. Min. Engs.*) extending through many years, present this common feature; that all of them are, to a striking degree, timely and suggestive, though few, perhaps, could claim to be exhaustive and conclusive. In other words, Professor Egleston, in his

constant survey of a wide range of professional topics, had the faculty of recognizing those which possessed immediate critical importance; and with regard to these, he contributed to the common stock of information, without pedantic conceit or futile delay, whatever knowledge he had acquired, whether by personal investigation or by observation or compilation."

Much more important to the world, however, was the ability which he repeatedly showed to recognize the time to inaugurate a new movement and the skill with which he then organized it and the never failing vigor, faith, and persistency with which he forced it to success.

List of Books and Papers Published by T. Egleston.

Catalogue of Minerals, Smithsonian Miscellaneous Collection, Vol. 7, Art. 9, 1863.

Catalogue of Minerals, arranged by their bases, Washington, 1863; also in 1866 for use of students of School of Mines.

Plan for a School of Mines, New York, 1863.

A Check List of the Silicates, New York, 1866.

Diagrams to illustrate the lectures on Crystallography, First Edition (3 editions), New York, 1866.

Agricultural Survey of the first hundred miles of the Union Pacific Railroad, New York, 1866.

Tables for the determination of Minerals, First Edition (5 Editions), New York, 1867.

Metallurgical Tables on Copper, Lead, Silver, Gold, etc. (2 Editions), New York, 1868.

Tables of Weights, Measures and Coins of the United States and France (3 Editions), New York, 1868.

Metallurgical Tables on Fuels, Iron and Steel (7 Editions), New York, 1869.

Blanks for collecting statistics on Iron and Steel Metallurgy, Pamphlet, New York, 1871.

Catalogue of the Arrangement of the Collections of the School of Mines, New York, 1871.

Comparison of the Notations of Faces of Crystals, New York, 1871.

Tables for the Collection of Iron Statistics, New York, 1871.

Comparison of the dimensions of American Blast Furnaces, New York, 1870.
Also Berg u. Huttenmännische Zeit., p. 21 1872.

Lectures on Mineralogy (3 Editions), New York, 1871.

Scheme for Qualitative Determination of Substances by the Blow Pipe, Amer. Chemist, Vol. 2, p. 383, 1872. Also in Smithsonian Report for 1872.

Labels for Mineral Collections, New York, 1872.

Researches on the Abrasive Power of Sand on Diamonds and other Minerals, Trans. Amer. Inst., 1872.

The Uses of Blast Furnace Slags, Trans. Amer. Inst. of Min. Eng., Vol. 1, p. 206–215, 1872.

Analysis of Furnace Gases, Description of the Orsat Apparatus, Trans. Am . of Min. Eng., Vol. 2, p. 226–240, 1873.

Angles of Tools, Horological Journal, April, 1873.

Investigations on Iron and Steel Rails, made in Europe in 1873, Trans. Amer. Inst. of Min. Eng., Vol. 2, p. 44, 1874.

Improvement in the Condition of Workmen, Trans. Amer. Inst. of Min. Eng., Vol. 3, p 24, 1874.

Analysis of Rocks, Trans. Amer. Inst. of Min. Eng., Vol. 3, p. 94, 1874.

Notes on the Treatment of Mercury in North California, Trans. Amer. Inst. of Min. Eng., Vol 3, p. 273–307, 1874.

Refractory Materials, Trans. Amer. Inst. of Min. Eng., Vol. 4, p. 257–273, 1874.

Investigations on the La Bastie Glass, New York, 1875.

Boston and Colorado Smelting Works, Engineering, London, Eng., Vol. 22, p. 199, 246, 289, 317, 1876.

Also Trans. Amer. Inst. Min. Eng., Vol. 4, pp. 276–298, 1875.

Hunt and Douglas Copper Process, Engineering, London, Eng., Vol. 22, p. 419, 437, 1876.

Canfield Mineral Dresser, Trans. Amer. Inst. Min. Eng., Vol. 4, p. 273–276, 1875.

Technical Education, Trans. Amer. Inst. of Min. Eng., Vol. 4, p. 96, 1876.

Sampling Ores in Colorado. Engineering, London, Eng., Vol. 22, p. 495, 1876.

Boracic Acid in Lake Superior Iron Ores, Trans. Amer. Inst. of Min. Eng., Vol. 5, p. 131–132, 1876.

The Commercial Analysis of Furnace Gases, Trans. Amer. Inst. of Min. Eng., Vol. 5, p. 487–494, 1876.

Brückner's Cylinders, for Roasting Silver Ores, Engineering, London, Eng., Vol. 22, p. 515, 1876.

Reese River Process for the Extraction of Silver in Colorado, Engineering, London, Eng., Vol. 23, p. 474, 1877.

Parting of Gold and Silver in California, Engineering, London, Eng , Vol. 23, p. 375, 1877.

Extraction of Gold, by Plattner's Process, in California, Engineering, London, Eng., Vol. 24, p. 119, 1877.

The Pelican Mill, Colorado, Engineering, London, Eng., Vol. 24, p. 297, 1877.

Hydraulic Mining in California, Engineering, London, Eng., Vol. 24, p. 353, 409, 445, 485, 1877.

Copper Dressing in Lake Superior, Metallurgical Review, Vol. 2, p. 227, 1878.

The Doyere Method of Analyzing Blast Furnace Gas, Met. Review, Vol. 2, pp. 53–67, 1878.

Copper Mining on Lake Superior, Trans. Amer. Inst. of Min. Eng., Vol. 6, pp. 275–312, 1878.

Thin Plates of Metal, Trans. Amer. Inst. of Min. Eng., Vol. 7, pp. 91–93, 1878.

Structure of Rails as affecting Railroad Accidents (read before N. Y. Acad. Sci.), abstract in Science News, Vol. 1, p. 68, 1878.

Researches on the Abrasion and Wear of Iron and Steel, Report of Progress, Trans. Amer. Inst. of Min. Eng., Vol. 7, p. 371, 1879.

Pan Amalgamation of Silver Ores in Nevada and Colorado, Engineering, London, Eng., Vol. 27, pp. 43, 128, 189, 369, 473, 491, 514, 1879.

The Chemical and Physical Properties of Steel Rails, Trans. Amer. Inst. of Min. Eng., Vol. 7, p. 371, 1879.

Treatment of Mercury in Northern California, Engineering, London, Eng., Vol. 28, pp. 239, 277, 331, 408, 464, 1879.

California Stamp Mills, Engineering, London, Eng., Vol. 30, pp. 19, 85, 163, 255, 338, 1880.

The Iron of our Railways, Science News, Vol. 1, p. 68, 1879.

The Law of Fatigue and Refreshment of Metals, Trans. Amer. Inst. of Min. Eng., Vol. 8, pp. 398–404, 1880.

Parting Gold and Silver, School of Mines Quarterly, January, 1880.

The Manufacture of Charcoal in Kilns, Trans. Amer. Inst. of Min. Eng., Vol. 8, pp. 373–397, 1880.

The American Bloomary Process for making Iron Direct from Ores, Trans. Amer. Inst. of Min. Eng., Vol. 8, pp. 515–550, 1880.

Treatment of Silver Tailings in Nevada, Engineering, London, Eng., Vol. 30, pp. 395, 451, 1880.

Treatment of Gold Quartz in California, Engineering, London, Eng., Vol. 31, pp. 246, 323, 403, 532, 605, 1881.

Copper Refining in the United States, Trans. Amer. Inst. Min. Eng., Vol. 9, pp. 678–730, 1881.

The formation of Gold Nuggets and Placer Deposits, Trans. Amer. Inst. of Min. Eng., Vol. 9, pp. 633–646, 1881.

The Cause of Rustiness and of some of the Losses in Working Gold, Trans. Amer. Inst. of Min. Eng., Vol. 9, pp. 646–650, 1881.

Parting Gold and Silver in California, Report of the Director of the U. S. Mint for 1880, pp. 356–363, 1881.

Investigations on the Ore Knob Copper Process, Trans. Amer. Inst. of Min. Eng., Vol. 10, pp. 25–57, 1881.

The Progress of Metallurgy of Gold and Silver in the United States, School of Mines Quarterly, Vol. 3, pp. 71–90, 157–171, 1882.

Presence of Tellurium in Copper, Trans. Amer. Inst. of Min. Eng., Vol. 10, pp. 493–495, 1882.

On Zinc Desilverization, Annals of the N. Y. Acad. of Sci., Vol. 2, p. 80, 1882.

Treatment of Enargite, School of Mines Quarterly, Vol. 4, pp. 5–9, 1882.

The Appointment of a United States Government Commission of tests of Metals and Constructive Materials, Trans. Amer. Soc. Mech. Eng., Vol. 3, p. 80, 1882.

The Method of Collecting Flue Dust at Ems on the Lahn, Trans. Am. Inst. of Min. Eng, Vol. 11, pp. 379–411, 1883.

Leaching Gold and Silver Ores in the West, Trans. Amer. Inst. of Min. Eng., Vol. 12, pp. 40–63, 1883.

An Accident to Steam-Pipes arising from the use of Blast-Furnace Wool, Trans. Amer. Soc. of Civil Eng., Vol. 12, pp. 253–266, 1883.

The Patio and Cazo Processes for Amalgamating Silver Ores, Annals of N. Y. Acad. of Sci., Vol. 3, pp. 1–66, 1883.

Some Researches on the Amalgamation of Gold and Silver, Trans. Amer. Inst. of Min. Eng., Vol. 12, pp. 379–386, 1883.

A Machine for testing the Physical Properties of Metals and Alloys, Trans. Am. Soc. Mech. Eng., Vol. 5, pp. 140–156, 1883.

Biographical Notice of Louis Gruner, Trans. Am. Inst. of Min. Eng., Vol. 12, pp. 126–130, 1883.

Russell's Leaching Process, Engineering, London, Eng., Vol. 38, p. 239.

Gases Contained in Steel, School of Mines Quarterly, Vol. 5, pp. 224–235, 1884.

Haswell & Whitworth's Steel Forgings, School of Mines Quarterly, Vol. 6, 216–224, 1885

Parting Gold ond Silver by Means of Iron at Lautenthal, Report of Director of. U. S. Mint for 1880, p. 353–366; also School of Mines Quarterly, Vol. 6, pp. 240–251, 1885.

Bessemerising Copper Mattes, School of Mines Quarterly, Vol, 6, pp. 320–335, 1885.

Going into Blast with Anthracite Furnaces, School of Mines Quarterly, Vol. 6, pp. 358–370, 1885.

The Separation of Silver and Gold from Black Copper at Oker, Report of Director of Mint on Prod. Gold and Silver in the U. S., 1884, pp. 599–604, 1885.

Treatment of Roasted Pyrites by the Longmaid & Claudet Processes for the Extraction of Gold and Silver, Trans. Am. Inst. Min. Eng, Vol, 14, pp. 98–118, 1885.

Parting Gold and Silver in the U. S. Assay Office, New York City, School of Mines Quarterly, Vol. 7, p. 1–23, 1885.

Basic Refractory Materials, Trans. Am. Inst. Min. Eng., Vol. 14, pp. 455–492. 1885.

Basic Open Hearth Process, School of Mines Quarterly, Vol. 7, p. 49–66, 1885.

Basic Bessemer Process, Trans. Am. Soc. Mech. Eng., Vol. 7, pp. 34, 80, 1885.

On Some of the Physical Properties of Iron and Steel, Trans. Am. Soc. Mech. Eng., Vol. 7, p. 249, 1885.

The Stetefeldt Furnace, Engineering, London, Eng., Vol. 40, p. 293, 1885.

Rolls for Crushing Ore, Engineering, London, Eng., Vol. 40, pp. 463–487, 1885, reprinted New York, 1886.

Cause and Prevention of the Decay of Building Stone, Trans. Am. Soc. Civil Eng., Vol. 15, pp. 647–716, 1886.

The Disintegration of the Egyptian Obelisk in the Central Park, New York, Trans. Am. Soc. Civil Eng., Vol. 15, pp. 79–84, 1886.

Working Placer Deposits in the United States, School of Mines Quarterly, Vol. 7, pp. 101–131, 1886.

The Parting Process used in the United States Mint, at Philadelphia, School of Mines Quarterly, Vol. 7, pp. 253–283, 1886.

The Point Shirley Copper Works, School of Mines Quarterly, Vol. 7, pp. 360–384, 1886.

The Mendheim Continuous Gas Furnace for Burning Fire-brick and Porcelain, School of Mines Quarterly, Vol. 8, pp. 34–54, 1886.

The Dunnachie Continuous Regenerative Gas Kiln for burning Fire-Brick, Pottery, etc., Trans. Am. Inst. of Min. Eng, Vol. 15, pp. 488–504, 1886.

Treatment of Gold in the Arrastra, School of Mines Quarterly, Vol. 8, pp. 126–135, 1887.

Drift Mining, School of Mines Quarterly, Vol. 8, pp. 204–220, 289–304, 1877.

The Metallurgy of Silver, Gold and Mercury in the United States in two volumes, Vol. I., Silver, 1887, 556 pp.

The Extraction of Copper at Agordo, School of Mines Quarterly, Vol. 9, pp. 124–139, 256–278, 1888.

A Glossary of Furnace Terms in English, French and German, Trans. Am. Inst. Min. Eng., Vol. 16, pp. 313–333, 1888.

Some Thoughts and Suggestions on Technical Education, Trans. Am. Inst. Min. Eng., Vol. 16, pp. 623–661, 1888.

The treatment of Fine Gold in the Sands of Snake River, Idaho, Trans. Am. Inst. Min. Eng., Vols. 18, pp. 597–609, 1889.

Catalogue of Minerals and Synonyms Alphabetically arranged for the use of Museums, Bulletin No. 33, of U. S. National Museum, 1889.

The Thies Process of Barrel Chlorination, School of Mines Quarterly, Vol. 11, pp. 138–147, 1890.

The worth of Manual Training, Educational Leaflet No. 57, of College for the Training of Teachers, 1890.

Cooking Schools, Educational Leaflet, No. 61 of College for the Training of Teachers, 1890.

The Metallurgy of Gold, Silver, and Mercury in the United States, in 2 volumes. Vol. 2, Gold and Mercury, 1890, 920 pp.

Obituary Notice of J. B. Mackintosh, School of Mines Quarterly, Vol. 12, pp. 256–259, 1891.

The Treatment of Copper Slates at Mansfeldt, School of Mines Quarterly, Vol. 12, pp. 85–117, 193–218, 1891.

Manufacture of Slag Bricks in Montana, School of Mines Quarterly, Vol. 12, 189–193, 1891.

Ancient Methods of Dividing and Recording Time in Japan, School of Mines Quarterly, Vol. 13, pp., 299–312, 1892.

Biographical Notice of Major Egleston of the Revolutionary Army, N. Y. Genealogical and Biographical Record, July, 1889.

The Life of Major-General John Paterson, G. P. Putnam's Sons, New York, 1895.

ENGINEERING TESTS ON DIRECT CURRENT ELECTRICAL MACHINERY WITH PRELIMINARY TESTS ON THE PROPERTIES OF CONDUCTORS.

BY GEORGE F. SEVER.

(Continued from page 136, Vol. XXI.)

19. Experiment 6.—Operation of a Compound Dynamo and Determination of the Compound Characteristic or "Working" Curve.

In the case of a shunt dynamo, the variation of the power delivered to the external circuits will cause the E. M. F. at the terminals of the machine to vary, unless the current in the shunt field windings is altered in accordance with the variation in power delivered. It is quite impracticable to do this when the power is rapidly fluctuating through wide limits, first, because it would necessitate constant attendance at the regulating devices of the various

machines, and, secondly, the variations could not be compensated for quickly enough to maintain the E. M. F. constant. This necessary regulation can be accomplished automatically and without the employment of mechanical apparatus by dividing the windings of the fields into two circuits, one known as the shunt winding, similar to that of the plain shunt dynamo, the other known as the series winding, of large wire and low resistance, which carries all of the total current output of the machine, as the series field coils, armature and external circuit are in series. The shunt winding gives the correct no load E. M. F. of the dynamo, while the series coil, with either the whole or part of the external current traversing it, increases the flux through the armature. This compensates for the loss of E. M. F. due to the armature reaction and dorp and the drop in the series field coils. If the number of series ampere-turns is large enough, the increased flux can be made more than sufficient to compensate for all the losses of E. M. F., and the external E. M. F. will rise with the increase of current in the external circuit. In lighting systems in isolated plants the over-compounding, as it is called, is about 2 or 3 per cent. In railway work the dynamos are usually over-compounded for 10 per cent., the E. M. F. rising from 500 volts at no load to 550 at full load. This regulation is entirely automatic and almost instantaneous. The amount of the compounding can be altered by placing across the ends of the series windings a German silver or iron shunt, which diverts part of the current from the series winding and prevents the E. M. F. from rising to as high a value as it would with the total current traversing the coils. By removing this shunt the full effect of the series ampere-turns can be made available.

Care must be exercised in the operation of a compound dynamo or of those dynamos in parallel, for if a machine is subjected to a considerable overload or to a short circuit, the E. M. F. and current will increase, and great strains will be produced in the machine and driving mechanisms. In the case of belted dynamos, the belt may fly off, causing damage to property and life. Severe sparking occurs at the brushes and commutator, leading to injury of the machine. This action is quite in contrast with that of the shunt dynamo, whose potential decreases with increase of load. The short circuiting of a shunt dynamo reduces its E. M. F. and current to zero.

Method.—Operation of the machine.

Observe the instructions given in Experiment 5—Part 1, before starting the machine. The following measurements can then be made:

(1) Resistance of shunt field coils, by Wheatstone Bridge.

(2) Resistance of the parts of the armature circuit, armature, brush contacts and leads, by fall of potential method.

(3) Resistance of series field coils, by fall of potential. The connections for a compound dynamo are shown in general form in Fig. 9.

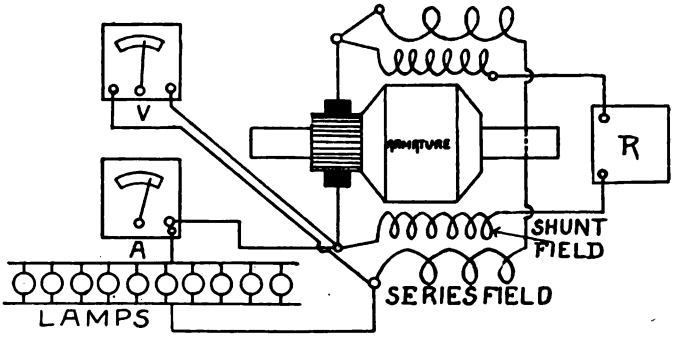


FIG. 9.

It is very important that a compound dynamo should be operated at its rated speed, otherwise the proper compounding effect is not obtained. See that the speed is right for the machine under test and then build up the E. M. F. to the correct no load value, by varying the resistance in the shunt field circuit. The external circuit can then be closed and a small load applied to the machine. The brushes can be adjusted to that point where there is the minimum sparking. When the load is applied, the E. M. F. should be observed, in order to ascertain if the series ampere turns are increasing the E. M. F. or decreasing it. In the latter event, the turns are acting against the shunt winding and the direction of the current through the former should be reversed.

The load can now be varied and its effect upon the E. M. F. noted.

With the machine running at a constant speed, note the compounding effect when the no load E. M. F. has different values.

20. The *compound characteristic* or "working" curve gives the relation which exists between the corresponding values of the terminal E. M. F.'s and the total current in the external circuit, the machine operating alway at its *constant speed.*

The curve which can be plotted from these values illustrates the compounding which occurs at this constant speed. If the machine is designed to maintain a constant E. M. F. at the terminals, the curve will be a straight line, using current values for abscissas and volts for ordinates. If the machine is over-compounded the curve will gradually rise with increase in load.

Method.—The E. M. F. of the machine can be adjusted to its value at no load, the load gradually increased and corresponding values of the terminal E. M. F. and external current can be read. Making these respectively the ordinates and abscissas of a curve, the action of the machine can be readily seen. The speed should be observed carefully so that if any change does occur, it can be recorded.

The forms of the curves are shown in Fig. 10.

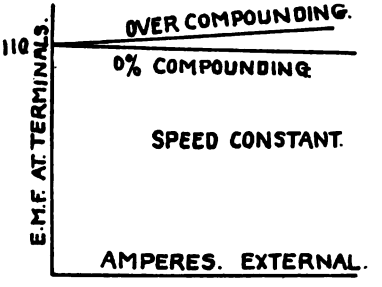


FIG. 10.

21. Experiment 7.—Operation of a Thomson-Houston Constant Current Arc Dynamo and the Operation and Studyof Arc Lamps.

The Thomson-Houston arc dynamo is a series constant current machine and is intended for use in connection with series arc and incandescent lamps. It delivers a constant current of 10 amperes with a variable potential, the value of this potential depending on the number of lamps connected to the machine.

The armature is of the " open coil " type, there being three sections or windings, one end of each coil being connected to a common point at the pulley end of the machine, while the other ends of these coils are connected to the three sections of the three-part commutator. This armature is spherical in shape and revolves between two cup-shaped pole pieces which nearly enclose it. The field magnets consist of two cylindrical cast iron cores with wrought

iron bars holding them in place, these bars also forming part of the magnetic circuit.

Bearing on the commutator are four brushes, two to a set, these brushes being carried by a movable set of arms or levers, by the movement of which the regulation is accomplished. The operation of this regulating mechanism should be carefully noted when running the machine. In large machines of this type, there is provided an air blower, the function of which is to provide a blast of air at the right instant to blow out the spark which occurs when the leading brush leaves a commutator bar.

There is placed upon the wall a regulator which controls the movement of the brush shifting apparatus. This consists of a pair of solenoids in series with the main circuit, which act on a pair of iron cores, lifting them when the current becomes greater than that for which it is set; this action opens the shunt circuit *A*, in Fig. 11, and forces the whole current to pass around the electro-magnet *M*, which controls the movement of the brushes. This magnet operates a lever which moves the brushes about the commutator, thereby causing the current to assume its proper value.

The action of the machine is stopped by short circuiting the armature by means of the switch *S*, placed on the frame of the machine. This prevents the current from passing through the field magnets and external circuit, and therefore stops the machine from exciting its field.

By studying carefully the internal connections of the armature, it will be seen that when one of the coils is connected to one set of brushes the other two coils are connected in parallel with each other and to the other set of brushes but in series with the first coil. When the maximum potential is required, the individual brushes of each set are shifted so as to be as close as possible to each other, while when the minimum potential is necessary these brushes are wide apart. Other types of machines for the same purpose as the Thomson-Houston dynamo, operate similarly, the potential being regulated by electro-mechanical devices.

(For a detailed description of this machine, reference can be made to a special hand-book relating to it or to Thompson's "Dynamo Electric Machinery.")

Connections of the machine are shown in Fig. 11.

22. *Switchboard.*—The arc lighting switchboard consists of two panels of slate supported in an iron frame, and carrying metal contact strips. In the front face of the outer panel are a number of rows of rubber bushings through which are passed brass connection plugs, these serving as the means for connecting the dynamo to the various lamp circuits.

All of the bushings of the same horizontal row to the *right* of the center of the panel are electrically connected, except those of the bottom row, and similar connection is made between the bushings to the *left* of the center. A brass strip is supported on the rear

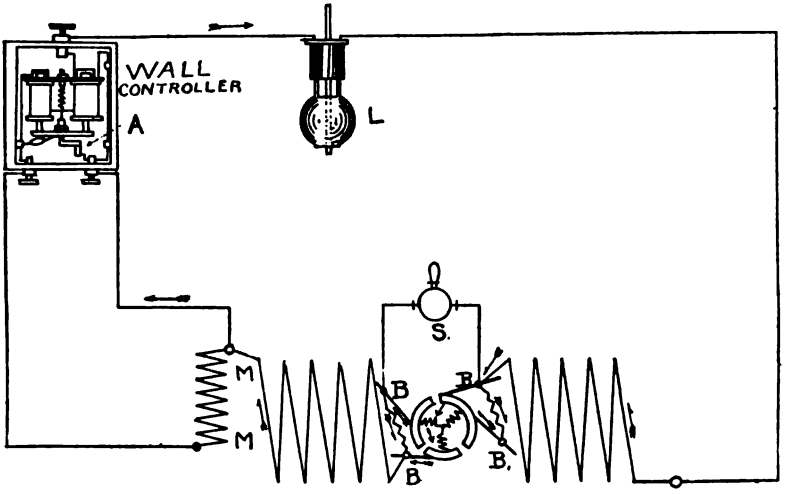


FIG. 11.

panel behind each vertical row of holes, and is furnished with bushings corresponding with those in the front rows. These strips can be put into electrical connection with any one of the horizontal conductors it crosses by the use of the brass plugs mentioned above.

In a standard panel the number of rows of holes arranged horizontally is equal to one more than the number of generators. The vertical rows are always twice the number of generators. The *positive* leads of the machines are attached to the binding posts on the *left* hand end of the horizontal conductors; the *negative* leads being connected to the corresponding binding posts at the *right* hand end of the board. The *positive* line wires are connected to the vertical straps on the *left*, and the *negative* wires to similar straps on the *right* of the center of the panel.

The holes of the lower horizontal row have bushings connected to the vertical straps only. Plugs, connected in pairs by flexible cable and inserted in the proper holes, serve to connect any of these vertical straps together as needed; normally independent circuits being thus interconnected when one generator is of sufficient capacity to supply these several circuits.

Operation.—Connect the dynamo terminals to the apparatus on the wall, switchboard and regulator, and connect lamps to the proper terminals of the board. This will illustrate the operation of entirely independent circuits.

Note the regulation of the machine when the number of lamps in circuit is changed and describe the operation of the machine. Note any peculiarities which attract attention.

23. *Study of an Arc Lamp.*—If two pieces of carbon are connected by wires to a proper dynamo, brought in contact and then separated a short distance, the current will continue to flow across the gap, producing the brilliant light known as the electric arc. When the arc is produced in air the carbon rods are consumed by the oxygen of the air. The positive carbon assumes a cup shape at the end, while the negative assumes a pointed form, in the case of a direct current open arc. About 40–50 volts are required to maintain a good steady arc and the usual current is from 6–10 amperes. Larger arcs are used in lighthouse service and for search lights, these sometimes taking as much as several hundred amperes.

In ten ampere arcs the positive carbon is consumed at the rate of about one inch per hour, in the open air, while the negative carbon is consumed at about half this rate.

In commercial lamps the mechanism is arranged to "strike" the arc by causing the carbons to touch and then separate them to the requisite distance to maintain a proper arc; the mechanism then feeds the carbons into the arc at the rate at which they are consumed. The mechanism should also cause the points to recede automatically in case the arc becomes too short; it should also bring the carbons together for an instant to strike the arc again in case the flame for any reason should go out.

In the "clutch lamps," a clutch is employed to pick up the upper carbon holder, the lower carbon remaining fixed. The clutch is worked by an electro-magnet or a number of magnets, through which the current passes. If the lamp goes out the mag-

net releases the clutch, the upper carbon falls by its own weight and touches the lower carbon, the current is re-established, and the electro-magnet causes the clutch to grip the carbon holder and lift it, thereby striking a new arc. If the arc grows too long the increased attraction of the magnet causes the clutch to slightly release its hold on the upper carbon holder, permitting it to drop slightly and thus shortening the arc to its proper length.

Note the regulation of the lamps which are connected to the dynamo, measuring the E. M. F. across the terminals of each, and the current required to operate them. Note the direction in which the light is thrown if the lamp is connected to the circuit the wrong way.

24. Experiment 8.—Operation of a Constant Potential Shunt-wound Motor and the Test for its Commercial Efficiency using the Prony Brake.

Part 1. Any direct current dynamo-electric machine that can be used as a dynamo can be used as a motor; therefore, the investigation of the operation and test of a motor is in many respects similar to that of a dynamo. These types of machines are perfectly reversible.

In the case of the motor, electrical energy is supplied to the armature and field coils, the machine being merely an apparatus for converting this energy into a mechanical form at the shaft or pulley.

In the case of a dynamo, however, the mechanical energy supplied to the shaft or pulley is converted into electrical energy by the armature's rotation in the magnetic field.

Motors are usually classed according to their field windings, these being known as *series*, *shunt*, *compound* and *differential*. The first three are identical with the corresponding windings of a dynamo, while in the differential form the winding consists of shunt and series coils, the latter acting in opposition to the shunt and weakening the field with the increase of load and current. The net result is the maintenance of a constant speed throughout the load limits.

The following discussion and tests relate only to the shunt motor, the series motor being considered in the next experiment:

The general equation for the current through the armature of a motor is: $C = \frac{E - e}{R}$. $\therefore E - e = CR$, which, multiplied by C,

gives $EC - eC = C^2R$. The total power supplied to the armature is EC, the loss in the armature due to this current is C^2R. The useful external work plus the losses, outside of the C^2R losses in the armature, are represented by eC. This follows from the conservation of energy and clearly indicates the importance of making the C. E. M. F. of large value. The efficiency of a motor depends upon the relation which exists between the output and input, and as eC closely represents the output, it is important that the value of the C. E. M. F. be high. Another factor of importance in a motor is its *Torque* or turning moment. In many types of motors this is of even greater importance than high efficiency, especially when great efforts are expected for short periods. The *Torque* of a motor is expressed in *foot-pounds*, or the number of pounds pull at 1 foot radius.

The equation for the C. E. M. F. of a motor is the same as for the E. M. F. of a dynamo

$$e = \frac{2\Phi Nnp}{60 \times 10^8}$$

The work done by the armature would be

$$Ce = \frac{2\Phi NnpC}{60 \times 10^8}.$$

The mechanical work done is,

$$\text{Foot pounds per minute} = \frac{2\pi LFN}{33\,000}$$

$$\frac{2\pi LFN}{33\,000} = \frac{2\Phi NnpC}{60 \times 10^8}$$

Eliminating constants and similar quantities, it is seen that

$$LF = \Phi Cn$$

or that the *Torque* is directly proportional to the total current in armature, the inductors in series and the flux through the armature.

From the equation for the C. E. M. F. it is seen that the speed depends directly upon the C. E. M. F. and inversely as the flux and number of inductors. Therefore, if the number of inductors on an armature is fixed, the speed can only be varied by changing the flux or the C. E. M. F. From the fundamental equation for a motor, $C = \frac{E - e}{R}$, with C and R fixed, the e can be varied only by altering

the value of E. Therefore, it follows that the speed also depends upon the value of the E. M. F. at the armature. On a constant potential system, the E. M. F. at the armature can only be decreased, this being effected by placing resistance in series with the circuit. If it is desired to increase the speed, the flux must be decreased, by decreasing the M. M. F. of the field coils. In a shunt motor this is accomplished by placing suitable resistances in the field circuit. In a differential motor this regulation is automatic.

The reversal of the direction of rotation of a motor armature in all cases, is accomplished by changing the magnetic relation which exists between the armature and field.

If the field magnetization remains fixed, the armature current must be reversed. Or, if the armature connection remains fixed, the field current must be reversed. The usual procedure is to change the armature connection, as it can be more easily accomplished.

25. In all shunt-wound motors, as in shunt dynamos, it is essential for high efficiency that the armature resistance be made low and the field resistance be made high. The C^2R losses in both circuits will then be a minimum, and the regulation of speed will be most perfect.

As the field coils are made of high resistance, they are connected directly to the circuit from which the machine is to be operated, while the armature, being of low resistance, needs to have starting

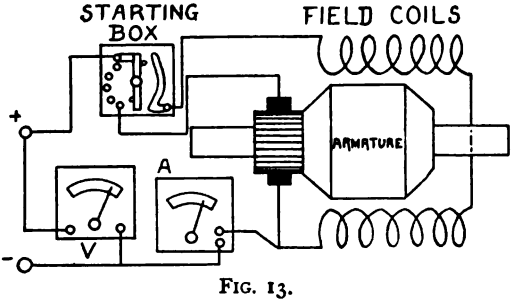


FIG. 13.

resistance placed in series with it. This resistance will permit enough current to pass to start the armature, being eventually cut out of the circuit, thus placing the full E. M. F. of the circuit across the armature. As was shown previously, the generation of the C. E. M. F. prevents any excessive current from passing through the low resistance armature.

This starting resistance is quite necessary for the reason that if the low resistance armature were connected directly to the E. M. F., a large inrush of current would occur and would blow the fuses or circuit-breakers. The arrangement of one form of starting box is shown in Fig. 12. The other terminal of the field and armature are connected as shown in Fig. 13.

The connections for operating a shunt motor are given in Fig. 13, the ammeter being inserted so as to measure the armature and field currents.

Some of the causes which prevent a motor from operating are as follows:

(1) Great overload preventing the turning of the armature.
(2) Excessive friction in some part.
(3) External or internal circuit open in some place.
(4) Wrong connections.
(5) Armature revolves at too great a speed.
(6) Armature revolves in wrong direction.

26. The following paragraphs contain elementary tests which can be undertaken to prove the discussion which precedes.

(1) Measure the resistance of the field coils by the Wheatstone bridge, and the armature by fall of potential.

(2) Make the proper connections for operating a shunt motor using a suitable starting box and placing an ammeter in both armature and field circuits and a voltmeter across the terminals. On starting up note the fluctuations in the *current* as the starting resistance is cut out. Note the speed and adjust the position of the brushes so that the *minimum* speed at no load is attained and also note that this is the position of minimum sparking. This position is known as the *neutral point.*

(3) Note the number of *watts* necessary to operate the motor at *no load.* This is the product of the E. M. F. of the circuit and the sum of the armature and field currents. This amount of power is required to overcome all friction and internal losses at no load, this of course being all the work that is done under this condition.

(4) Determine from the instrument readings and the equations given on page 32 the value of the C. E. M. F. at no load. Increase the load on the motor and note what change in speed occurs. From this can be calculated the percentage by which the C. E. M. F. is decreased. Explain the fact that only a small cur-

rent passes through the armature when running without load and that this current increases with load on the motor.

(5) Study of speed regulation. (*a*) With the armature running with no load, move the brushes to and fro a short distance about the commutator, noting the resultant change in speed. This is a limited method of regulation and if carried too far may result in bad sparking. The number of effective inductors is altered, thus varying the speed.

(*b*) In the field circuit can be inserted a variable rheostat, by means of which the field current can be varied and the flux altered. The speed should vary almost inversely as the flux.

(*c*) In the armature circuit can be placed a variable resistance which will alter the E. M. F. at the armature terminals and vary the speed. Note the effect upon the speed of increasing the load under these conditions and explain the result.

(*d*) Investigate the methods of reversing the direction of rotation of the armature.

27. Experiment 8.—Part 2. Commercial Efficiency of a Constant Potential Shunt Motor using the Prony Brake.

This test illustrates one of the simplest combined electrical and mechanical methods for determining the efficiency of an electric motor. In order to insure the accuracy of the results, it is neces-

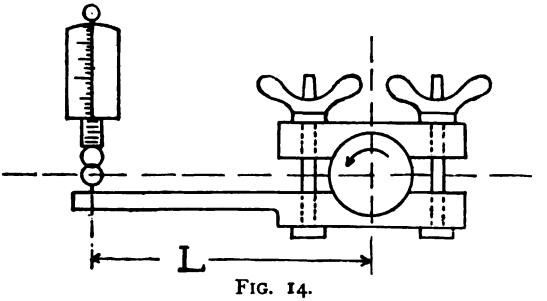


FIG. 14.

sary to exercise considerable care in making the readings of the various instruments, especially the speed recorder.

The Prony brake, which is employed in this experiment, in its simplest form, consists of a lever arm of wood or metal with suitable means for clamping it to the pulley or fly wheel of the machine under test, thus tending to make it rotate due to the friction

of the clamp on the pulley. The tendency to pull or rotate is measured by a spring balance or weights attached to the end of the lever arm.

Fig. 14 illustrates a simple form of this brake, applicable for most purposes. The brake is made of two wooden pieces held together by bolts with wing nuts, by means of which the pressure on the surface of the pulley can be adjusted, thus altering the force due to friction and the pull at the end of the lever arm. By measuring this pull, the speed of rotation, and the length of the lever arm, the power developed can be readily calculated.

Method.—Work is equal to the product of force and distance or FL, and power is equal to work divided by time, or

$$\frac{FL}{T} = Fv, \text{ where } v = \text{velocity.}$$

The distance L, from the center of the shaft to the point of application of the force resisting the tendency of the lever to rotate, is ascertained by careful measurement. In one revolution of the pulley, the distance through which the point of application of the force would travel if allowed to do so, would be equal to $2\pi L$, and if the number of revolutions per minute is N, the power, in foot-pounds per minute, is

$$\text{Power} = 2\pi LNF.$$

To reduce this to horse power, it is necessary to divide by 33 000, the number of foot pounds per minute equivalent to one horse power. To employ this method in the determination of the efficiency of an electric motor, it is necessary to take the following readings:

(1) E.M.F. at the terminals of the motor.
(2) Amperes in the external circuit.
(3) Speed at every load.
(4) Pull in pounds at end of lever arm.
(5) Length of lever arm.

(1) Determine the efficiency of the motor assigned, at approximately ¼, ⅜, ½, ⅝, ¾, ⅞, full load, and ¼ over load, plotting a curve showing the commercial efficiency of the motor. Use watts or horse power output for abscissas and commercial efficiency for ordinates.

(2) Determine the values of the *Torque* and plot in the form of

a curve on the same sheet as the efficiency curve, using values of current for ordinates and values of the torque for abscissas.

(3) Plot a curve on the same sheet, showing the relation between speed and horse power output, using values of the output for abscissas and speed for ordinates.

(4) Plot curve on same sheet between values of H.P. input and H.P. output, using the first for ordinates and the second for abscissas.

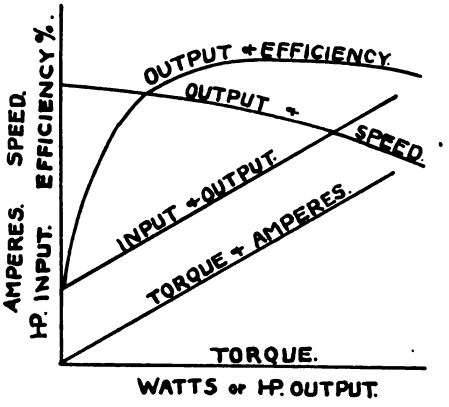


FIG. 15.

Fig. 15 shows the forms of the various curves. From the appearance of these curves, conclusions as to the performance of the machine can be readily drawn.

28. Experiment 9.—Operation of a Constant Potential Series Motor (Railway Motor) and Commercial Efficiency test using the Prony Brake.

The series motor on which this investigation is to be conducted is designed for use in street railway service and is intended to operate with a potential of 500 volts at its terminals. In a series motor the field winding and the armature are placed in series, the same current passing through both. The cross-section of the wire on the field is large and the number of turns is small as compared with the shunt motor field winding. Therefore the resistance of the field is small and the C^2R loss in this part of the circuit is kept low. The armature resistance is also made as small as possible in order to reduce the C^2R loss and to obtain good speed regulation.

The main point of difference between this type of motor and the shunt motor is that the shunt motor maintains a nearly constant

speed with a varying load, whereas the speed of a series motor varies greatly with the load. When the load increases the speed decreases, and when the load is decreased the speed rises, and if the external mechanical work done by the motor is zero and the resistances due to the friction of the bearings and commutator are not great, the speed may attain a high and dangerous value. The speed will rise to a point where the power input is just balanced by the internal losses and the friction in bearings and gearing.

As has been shown, the speed of a motor depends upon (*a*) the number of lines of force through the armature or strength of field, (*b*) the E. M. F. at the brushes, and (*c*) the number of conductors in series with each other on the armature. This latter is fixed once for all if the brushes are fixed in position so that the speed depends upon the other two factors. In the case of a shunt motor the field is of nearly constant strength, so that the speed would be dependent upon and nearly proportional to the E. M. F. at the brushes.

In a series motor both the field strength and E. M. F. at brushes vary with the work done, so that the speed may vary within wide limits.

In the shunt motor as the field is constant, the torque will be nearly proportional to the current in the armature. In the series motor the torque, being the product of field strength and armature strength, is greater at starting when the largest current is passing through the armature. This feature of a series motor is its most important characteristic.

As the load on the motor decreases the current also decreases, producing thereby a weaker field and at the same time permitting an increase of E. M. F. at the armature terminals or brushes.

By referring to Fig. 16, the above changes can be more readily followed.

When the load is decreased at *P*, the pulley or car wheel, the resistance to rotation becomes less and the armature speeds up; this increases its C. E. M. F. and consequently reduces the current, as in a shunt motor. In the case of the series machine, however, this decrease of current also weakens the field, necessitating a further increase in speed to keep the C. E. M. F. up to, and the current down to, their proper values; the machine always automatically adjusting its C. E. M. F. so as to take a current proportional to the load.

If the load increases a larger current is required, therefore its speed falls and its C. E. M. F. decreases sufficiently to permit the necessary current to flow. When the load is reduced a smaller current is required, therefore the armature speeds up and increases its C. E. M. F. and reduces the current to its proper value.

These variations in speed are, however, as has been already pointed out, much greater in the series than in the shunt motor on account, not only of the variations in the field strength with the variations in the load, but also to the varying E. M. F. across the armature terminals.

When the armature is held stationary the series motor exerts its maximum torque, for the current obtained from a constant potential source is a maximum, its value being simply dependent on the ohmic resistance of the windings. This feature is very desirable in the application of motors to any duty where heavy starting torque is required, as in the case of elevators, hoisting apparatus and electric traction.

In order to regulate this type of motor it is necessary to use an external resistance in series with the machine, this being decreased as the load is applied and inserted as the load is decreased. From the above it will be understood that the speed and torque vary inversely. The current in a series motor is equal to

$$C_t = \frac{E-e}{R_a+R_f}$$

and the counter E. M. F.,

$$(e = E - C_t R_a + R_f)$$

where

R_a = resistance of armature.

R_f = resistance of field.

If

S_a = number of turns in the armature.

S_f = number of turns in the field.

K = a constant.

then

$$\text{Torque} = KC^2 (S_a + S_f)$$

that is, the torque is proportional to the *square* of the current.

29. *Operation.*

(1) Determine the resistance of the field and armature by fall of potential method *before operating*.

(2) Operate the motor from 110 volt circuit in order to study its action with change of load and also with change of E. M. F. applied. Determine C. E. M. F. at the speeds and currents noted.

30. *Test.*—Connections are shown in Fig. 16.

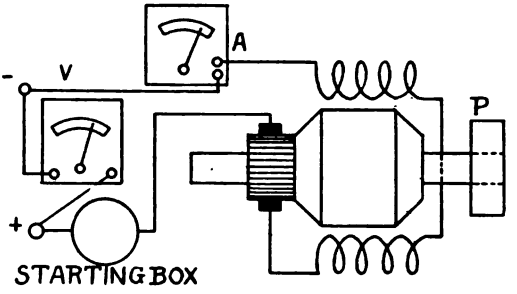


FIG. 16.

(3) After this has been done the motor can be operated on the 500 volt circuit and a Prony brake test made for its commercial efficiency. This test will include the losses in the gears and bearings of the shaft or axle carrying the large gear.

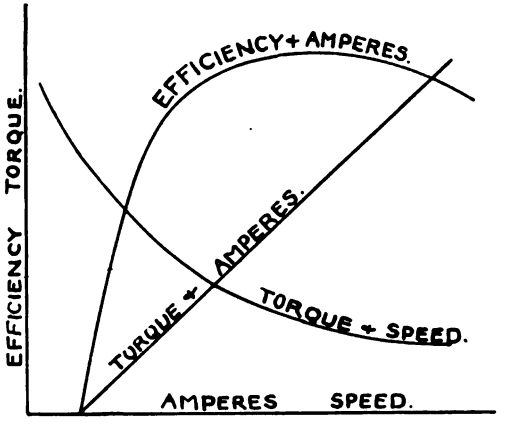


FIG. 17.

(4) From the observations made of the current, volts, speed, and pull on the brake, calculate the efficiency and plot curves as shown in Fig. 17, between % efficiency and amperes, torque and amperes, and speed and torque.

31. Experiment 10.—Test for the Commercial Efficiency of a Dynamo or Motor by the "Stray Power" Method.

This method consists in measuring the core and friction losses at the different speeds and field strengths which occur in operating a machine from no load to full load. The two great advantages in using this method are (*a*) the fact that only a small per cent. of the total capacity of the machine is employed, thus saving energy, and (*b*) the accuracy obtained is greater than when using a combined mechanical and electrical method.

This test differs in a number of ways from those employing mechanical dynamometers. These are that electrical measurements only are employed and that instead of the whole output and input of the machine being measured, the value of the stray power losses only are determined. The first gain by this method is that arising from not being compelled to operate the machine at full load conditions for long periods, thereby wasting energy: in the second place the stray power losses, which usually form a small per cent. of the total input of the machine, are measured directly and very accurately. In case any error is made in their determination, this error forms a small per cent. of a small per cent. (as the total losses are generally small in amount) and therefore does not offer the same opportunity for vitiating the results as does a like per cent. error while measuring the efficiency by any other combined electrical and mechanical method, involving the measurement of the total input and output. Therefore, for exact determinations of the commercial efficiencies of all direct-current dynamos and motors this method is recommended.

32. The losses in a dynamo or motor can be divided as follows:

1. Electrical or Copper Losses.

(*a*) C^2R in armature conductors.
(*b*) C^2R in brushes and brush contacts.
(*c*) C^2R in armature leads.
(*d*) C^2R in field windings, shunt and series.

In the case of a self-excited dynamo, the losses in the field rheostats are to be added to the other losses to give the total loss.

2. Stray Power Losses.

(*e*) Bearing friction and air friction or windage.
(*f*) Friction of brushes on commutator.

(g) Hysteresis in the armature iron.

(h) Eddy current loss in iron of armature and pole tips and copper of armature.

(a), (g) and (h) are losses in the armature: (b) and (f) are commutator losses: (d) field losses: (e) friction losses.

The determination of the C^2R losses in any machine is comparatively simple, as it is only necessary to measure the resistances of the electrical circuits and the values of the currents in them. The loss in any part is then equal to C^2R watts. The method of determining the total stray power losses of a dynamo or motor is as follows: the machine should be run *as a motor* at those speeds at which it ran when operating under working conditions from full load to no load. In the case of the testing of a *dynamo*, the voltage at the terminals should be equal to the potential when operating as a dynamo plus the CR loss over the internal resistance of the machine. While thus running as a motor, the field currents hould correspond with those which were used when the machines was operating as a dynamo.

In the case of a testing of a *motor*, the voltage at the terminals should be equal to the potential of the circuit on which it is to be operated, minus the CR loss over the internal resistance of the machine. The field currents should correspond in the two cases.

Under the above conditions, the product, in watts, of the E. M. F. at armature terminals and current in armature, plus the C^2R loss in the field circuits would equal the power necessary to operate the machine at that speed.

$(E_a \times C_a) + C_f^2 R_f =$ watts necessary at no load at N revolutions per minute.

$(C_a^2 R_a + C_f^2 R_f) =$ total copper losses.

$[(E_a \times C_a) + C_f^2 R_f] - (C_a^2 R_a + C_f^2 R_f) =$ stray power losses.

The efficiency of the machine, at any load, would be equal to the input minus the losses divided by the input, in the case of a motor; while in the case of a dynamo it would be the output divided by the output plus the losses. Therefore if the condition of load is known, the C^2R losses can be calculated, and the stray power losses for the corresponding speed and field strength added to them to give the total losses. If a set of readings of the stray power losses has been made over the normal range of speeds and corresponding field currents, and these plotted in the form of curves, the proper value for this loss under any normal condition can be readily ascertained from the m.

The friction and hysteresis losses vary approximately as the speed, while the eddy current loss varies as the square of the speed. The determination of these various losses can be made by using suitable methods. The friction losses can be determined by operating the machine by another motor directly connected to its

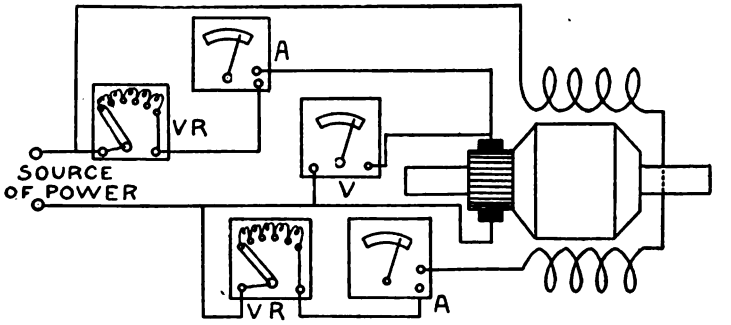


FIG. 18.

armature. In using it in this manner it becomes an electrical dynamometer, and it is important that it should have been carefully calibrated for such work.

As the hysteresis loss varies as the speed, and the eddy current loss as the square of the speed, the machine can be operated at

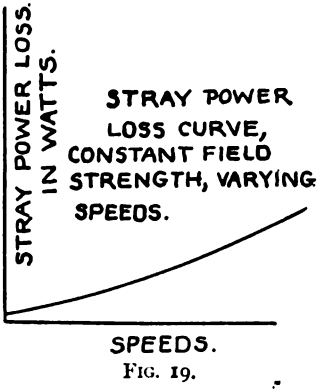


FIG. 19.

various speeds with a constant field strength and these individual losses calculated from the observed results.

Reference can be made to the following articles for a further discussion of this method:

Thompson's Dynamo Electric Machinery, pp. 791–793.

Jackson's Electromagnetism and the Construction of Dynamos, pp. 249–253.

33. The electrical connections and the location of the neces-

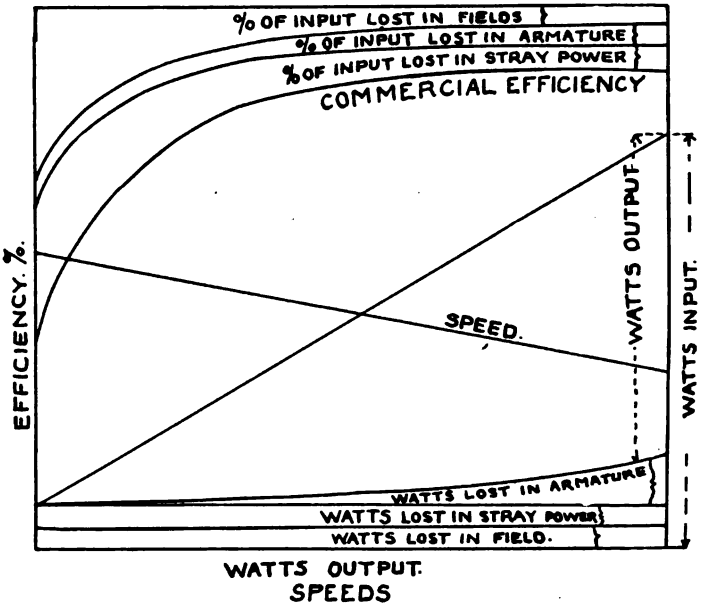


FIG. 20.

sary instruments for this test are shown in Fig. 18, the machine being operated as a motor from a source of power.

The method of expressing the results graphically is shown in Figs. 19 and 20.

THE PROGRESS OF ORE DRESSING.*—III.

By C. BLÖMEKE.

(Continued from page 170, Vol. XXI.)

II. Magnetic Separation.

The magnetic process, invented by the American engineer Wetherill, director of the Lehigh Zinc and Iron Co., at South Bethlehem, and used in practice, is a great step in advance in the art of ore dressing, because it enables us to separate a number of weakly magnetic minerals, without previous treatment (roasting), which could not otherwise be separated on account of their small difference in specific gravity, or would have had to be roasted in order to make them magnetic enough to be susceptible to treatment with the ordinary magnetic apparatus.

For instance, the mineral Franklinite, can be separated from the zinc sillicate Willemite of New Jersey, with a current of 6 to 8 amperes and a tension of 12 to 16 volts, and garnet containing but 4 % Fe and 12% Mn can then be separated from the latter by double the current.

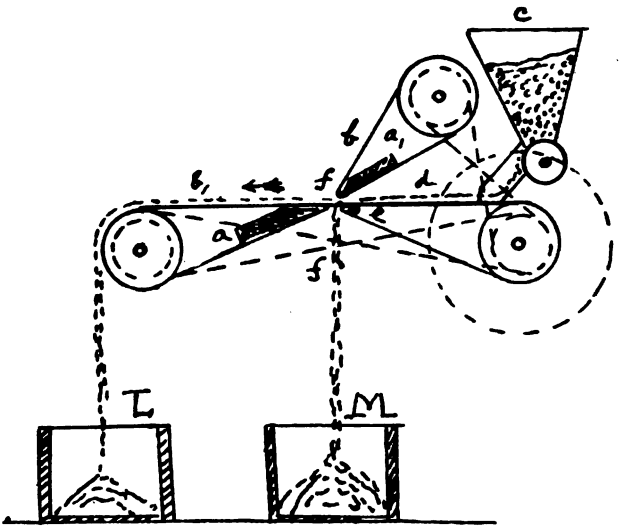
Siderite, unroasted, is attracted with the same current as Willemite, and in this way separated from zinc blende. Beside these minerals, braunite, hematite, limonite, titaniferous iron ore, and others containing manganese and iron, can be separated from each other by the Wetherill apparatus without previous roasting. As regards metals, iron, nickle, cobalt, manganese, chromium, cerium, titanium, paladium, platinum and osmium, can be separated, while formerly, manganese, and iron, were the only ones attracted by magnetic separators. The manganese compounds are more magnetic than the similar compounds of iron.

The following metals are non-magnetic for the Wetherill separator: bismuth, antimony, zinc, tin, cadmium, sodium, mercury, lead, silver, copper, gold, arsenic, uranium, rhodium, iridium and tungsten.

The improvement in the Wetherill apparatus consists mainly in the fact that both poles of an electro-magnet are in the shape of 300 mm. wide shoes, and are placed only 10 mm. apart, by which means a strongly magnetic field is induced at the points of the

* Translated by Charles Fulton from the "Berg und Hütten mannisches Jahrbuch."

shoes. The mineral is carried to this field by a belt (see *d* of sketch), where the magnetic particles are held suspended over the space by the attraction of the magnet. Another belt passing



around one pole of the magnet *b*, takes the magnetic minerals from the field and deposits them in the box *L*. The two belts are separated by the same space (3 mm.) as the poles of the magnet. The small rollers around which they pass at the poles are movable so that the discharge space for the non-magnetic minerals falling into the bin *M* can be adjusted.

In actual practice this magnetic process has been found to be very serviceable, as has been demonstrated at the works of the Lehigh Zinc and Iron Co., South Bethlehem, and at the Hill mine of the Sterling Iron and Zinc Co. in Sussex County, New Jersey.

These last works are described most thoroughly with illustrations in No. 4 of the *Engineering and Mining Journal* for 1897, and in the *Zeitschrift für Elektrochemie*, Heft. 17, 1897. A Wetherill plant will soon be installed in Germany at Neunkirchen in the Siegen district for treatment of siderite-blende middle product.

The mill of the Hill mine is designed to treat 300 tons of Franklinite, Willemite ore per day, a much larger quantity than is treated by any European mill.

The ore from the mine is separated first by means of a grizzley into coarse of over 40 mm. and mine fines below 40 mm. The

coarse goes directly to a jaw crusher in connection with a trommel of 25 mm. mesh. The coarse from this trommel goes to a picking table and the fines go to an elevator by means of a belt. The mine fines are dried automatically in an Edison dryer, consisting of six heated inclined chutes, covered or lined with iron plates. The ore is forwarded in the chutes by travelling shovels as it dries to the elevator, already mentioned, which elevates the fines from the first trommel, into another trommel also of 25 mm. mesh. The coarse from this then goes to a double jaw crusher, as do also the complex ores from the picking table, and are further crushed. Then this crushed material with the fines of the above trommel go to a third trommel of 12 mm. mesh. The coarse from here go to two rolls, where it is crushed down to 6 mm. In connection with these rolls are three trommels which give their coarse material over 6 mm. to two fine crushing rolls which crush down to 2½ mm. size. The crushed material from these last rolls is lifted by bucket elevator with the fines of less than 6 mm. of the 3 above mentioned trommels into another set of 4 trommels of 2½ mesh. The coarse from here of over 2½ mm. goes to a third set of rolls which delivers its product to the elevator which in turn returns it again to the last four trommels.

Hence all the ore, with the exception of what is retained on the picking table undergoes a gradual crushing. The final product of 0 to 2½ mm. size is transported by means of belts into six storage bins, below each of which is placed a Wetherill double separator. The pure Franklinite which these machines separate goes by belt to an elevator which delivers it into bins above the railroad track. The rest of the product of this preliminary separation goes by means of belts and an elevator into four trommels of 6, 8, 12 and 20 mesh per running centimeter, equivalent to 1.66–1.25, 0.83, 0.20 mm. holes and is separated into the sizes of 1.66 to 2½ mm., 1¼ to 1.66 mm, 0.83 to 1¼ mm., 0.20 to 0.83 mm. and 0.00 to 0.20 mm.

These sizes drop directly into bins which they are distributed to 31 Wetherill separators. The Franklinite product goes to the Franklinite bins by means of belts and bucket elevators, while the non-magnetic product ($Zn_2Mn_2SiO_4$) goes to Harz jigs and is there separated into the gangue, limestone and zinc ore (zinc silicate) with the exception of the 0 to 0.2 mm. size, which contains very little limestone.

The waste waters from the jigs go by overflow launders into clearing basins where the settled slimes are transported by car to an elevator which lifts them to the dump.

The works of the Lehigh Zinc and Iron Co. of South Bethlehem treated 4,812 tons in February, 1897, equal to 115 tons or 1,016 kg. per separator, or to 8 tons per separator per shift.

These works could be greatly improved upon by the use of the Gröppel automatic ore feeder and the Pope-Henneberg wind sifter.

At present, the ore is separated by a grizzley into fine and coarse, the latter is fed by hand to a jaw crusher and the first is lifted irregularly, as it dries, on the dryer, by an elevator for the further treatment of the mill.

The apparatus treating the ore cannot be fed as regularly by this method as if the Göppel automatic ore feeder were employed. In this case, both the coarse above 40 mm. and the fines, would have to be dried. This could be done best in a funnel-shaped automatic discharge furnace, such as is used in calcining siderite or limestone. The dried ore would be lifted into a storage bin and from there fed into a trommel with 40 mm. mesh, instead of over a grizzley. The feeding would be done by a Gröppel automatic feed. The coarse above 40 mm. would fall directly into a jaw crusher, or it could, as in a wet dressing mill, be charged on a travelling belt, where the barren pieces could be picked out, thus reducing the amount of material.

This first delivery trommel, and the trommel between the jaw crusher and the main picking table, could be connected with an exhaustor to prevent too much dust in the following trommels and in the mill building.

In place of the last and finest trommel of 0.83 mm. mesh, and, perhaps that of 1.25 mm. mesh, a Pope-Henneberg wind sifter would deliver the sands of .2 to .83 mm. and .8 to 1.25 mm. freer from dust, so that in the jigging of the non-magnetic product less slimes would reach the clearing basin, and hence less zinc ore be lost in the tailings, since the exhaustor in connection with the wind sifter would take all dust into the final smallest size of 0 to perhaps 2 mm.

B. The Dressing of Gold Ores.

In the mechanical dressing of gold ores, as well as in the preparation of gold ores for wet extraction processes, several improvements are to be recorded.

1. *The Crushing of the Ores.*

Formerly gold-bearing ores were almost exclusively crushed in stamps after some hand picking, and the first stamp mills were probably erected in Hungary. In these the ores were crushed with and without amalgamation with light square stamps, weighing up to 125 kg. In recent times the California stamp mill has been introduced as, *i. e.*, at the gold mine Muzari at Brad.

If, beside native gold, auriferous pyrite, zinc blende or galena occur in the quartz, the Hungarian treatment is to dress out first the pyrite, blende and galena by means of crushing, jigging and slime treatment, without reference to the way the gold occurs. All the tailings are also stamped fine with mercury.

At the beginning of the California gold discoveries, the old Hungarian stamp mill with 250 lb. 3-part stamps was used, then with increased transportation on account of its small capacity it was replaced by the so-called California stamp mill, having stamps of from 750 to 850 pounds and 80 drops per minute (compare No. 24 des Glückauf, 1894).

The crushing of gold ores in California is described by J. H. Hammond in the year-book of the California State Mining Bureau, 1888, practically as follows: The ore is separated into coarse and fines by means of grizzleys, the former being crushed by jaw crushers, small enough to be fed to the stamps. Great attention is paid in California to the site of a crushing mill, as the cost of crushing is greatly dependent on it. The arrangement of apparatus, wherever possible, is such that the ore passes from one to the other by gravity.

In place of feeding the coarse pieces to the jaw crusher by hand this is now done by an automatic ore feeder. The crusher is placed directly next to the bin, which has a door at the bottom controlled by a cog wheel, thus regulating the feed of the ore. This arrangement assures a continuous feed, and increases the capacity of the crusher, while saving the labor of two to three hands, in treating 40 to 50 tons of hard ore in 5 to 7 hours.

The ore crushed by the jaw crusher goes in with the mine fines. Where there is sufficient slope available, two jaw crushers are recommended, one for coarse and one for fine crushing, so as to feed the stamps finer material, and thus increase their capacity.

Automatic feeders have also been applied to the stamps, increasing their capacity 15 to 20 %. The Challenge feeder is

considered the best one. The Tullock-Hanford, and roller feed arrangement are also satisfactory for some ores. The last are considerably cheaper than the Challenge. The Challenge costs $250 in San Francisco.

The width of the stamp mortar box is determined by the character of the ore. Narrow mortars have faster discharge, but a quick discharge is not always desirable if amalgamation takes place in the mortar. With hard quartzy ores, the sieves or screens often suffer breakage, with narrow mortars. This is very often the cause of unnecessary expense and delays. There are various kinds of sieves—steel, brass, iron and zinc. In the zinc screens the openings are cut either round or as long slots. The Plymouth Consolidated Company in Amador County uses zinc screens in its stamp mill. These screens are not as thick as those of Russia iron and hence allow of a quicker discharge of the ore. Steel wire screens are not much in use as they have a tendency to rust. The discharge of the brass wire screens is greater than that of punched metal screens.

The capacity of stamps is mainly dependent upon—weight of stamp, height of drop, number of drops per minute, height of discharge, mesh of screen, width of mortar and on the character of the ore. Hard ores and clayey ores, with slow discharge of clayey slimes, decrease the capacity. A stamp of 900 to 950 pounds, 6″ to 7″ drop, 85 to 95 drops per minute has an average capacity of 2¼ tons per 24 hours.

In recent times, chrome steel shoes and dies have been introduced and have proved better than other kinds of steels. In some mills, steel shoes and iron dies are used. The last wear more evenly than steel dies.

As regards the amount of water required for stamps, Hammond states that clayey ores and pyriteferous ores require a great deal of water. The amount varies between 1,000 and 2,400 gallons per ton.

The California stamp mill have almost uniformly, single discharge. The arguments against double discharge are :

1. The difficulty of arranging the copper plates.

2. The large quantity of water which is required, particularly where concentration follows.

3. The ore is discharged too quickly and therefore not sufficiently amalgamated.

For some kinds of ores the double discharge is to be recommended, *i. e.*, when ores are very pyritiferous and cannot be amalgamated in the mortar, particularly when those ores are tough, because then they are apt to be overstamped.

With some ores, the stamps crush more ore than the screens can discharge, thus producing much slime, which is a considerable disadvantage in pyriteferous ores, causing loss in gold, by stamping some gold into float gold which cannot be saved.

The Colorado stamp mill differs according to the article in, Nr. 24, des Glückaūf, 1894, from the California stamp mill in that its stamp weighs only 550 pounds, while the height of drop is 20 inches, and the number of drops 30 per minute, while in some of the California mills the drop is 5'and 90 to 105 per minute. The Colorado stamp mill is in use in Gilpin County, Colorado.

While a stamp of the Colorado system has a capacity of 1 ton per 24 hours, the California stamp has a capacity of 2½ to 3 times as much in stamping ores of similar hardness, which difference is accounted for by the great depth of discharge of the first mentioned. The Colorado stamp has a wide mortar, this with the great height of drop, small number of drops, and the lesser agitation of the water, tend to crush very fine the pyrite which contains the gold in an exceedingly finely disseminated state. The frequent up and down motion of the pulp brings the gold constantly into contact with the inside plates, so that two-thirds of the amalgamation takes place inside the mortar. This method is suitable to the character of the Gilpin County ores, which contain 5 per cent. of pyrite and other heavy sulphides, which carry the very finely divided gold. The gangue is principally feldspathic.

Compared with this, the ore of Amador and Calaveras County, California, contains only 1 to 2 per cent. of pyrite, which carries the gold much coarser and in a less combined state, than the Gilpin County ore. The gangue in the California ore is quartz.

According to Professor Schulz (No. 18 des Glückaūf, 1894) the stamp mills, treating the free milling gold ore of Lawrence County, and situated on the Whitewood River, near the towns of Lead,Central City and Deadwood, have 80, 120, and 160 stamd respectively. The mills receive the ore from the gold belt, without previous sorting or picking, the coarse being first crushed in jaw crushers or Gates gyratory crushers. The ore is separated by a grizzly of 38 to 50 mm. spaces into coarse and fine.

The gold is carried in hornblende, quartz and slates. The free gold is in a very fine state. The auriferous sulphides are finely disseminated generally and amount to about 7 per cent. of the ore

A jaw crusher of 310×228 mm. jaw opening suffices to crush the ore for 20 stamps which treat including the mine fines, 90 tons per 24 hours.

It is of interest, that the Gates mill has replaced the jaw crusher, as *i. e.*, in the Golden Bar and the Homestake mills. Two Gates crushers crush the ore for 240 stamps. The hourly capacity of a No 6. Gates crusher is about 25 tons, and it replaces 12 Blake crushers of the above mentioned size. The crusher head is made of forged steel and the mortar is lined with 12 plates of hard iron. The power required for such a crusher is 60 H. P. The discharge opening is 0.8 m. in size. The cost of such a machine is 15,000 marks.

The ore crushed by such a crusher is fed to the stamps by a Heudy-Challenge or Tulloch automatic feed.

The water consumption for each stamp amounts to 1,274 cubic meters per 24 hours.

According to Schmeisser (Goldvorkommen, etc., in Australia) dry stamping has been introduced in Colorado in connection with Tellurium ores, where the problem of treating these ores has been solved by cyaniding, and chlorination after careful roasting at a low temperature, so that in recent times there has been a transition from smelting to chemical treatment.

According to C. E. Burger in the *Engineering and Mining Journal*, 29th of January, 1898 (see also B. u. H. Zeit. no. 19, 1898), the cyanide process in the Boulder county district, Colorado, has not satisfied expectations, and only proved successful in a few mills, where the ores have been changed so much that the gold is perfectly free. In cyaniding the ores, great difficulty was encountered in leaching the gold from the finely stamped ore on account of their limey and clayey nature. The Delano Mining and Milling Co. has therefore decided to adopt the chlorination process. In their mill, which has a capacity of 50 tons daily, the ore is first crushed in a Blake crusher, then in rolls. It is then dried in a rotating iron cylinder, and roasted in a Pearce oxidizing furnace. The ore contains marcasite, pyrite, lime and magnesia-bearing gangue, and in tellurides contains principally sylvanite and petzite, but also, calaverite, hessite, telluride of lead, telluride of bismuth and telluride of iron.

In older mills in the Transvaal (Schmeisser; Ueber Vorkommen und Gewinnung der nutzbaren Mineralien in der Sudafrikanishen Republik, 1894), the jaw crusher is also used in crushing ores, and in newer mills the Gates crusher is also employed. The ore crushed by these machines is combined with the mine fines, as in Colorado and California, and goes into bins from where it is fed through launders in connection, in most cases, with Challenge automatic ore feeders, to the stamps.

The stamp mills are constructed similar to American mills, but the weight of the stamp has been increased from 295–340 to 450 kg. since the ore has changed into the unaltered conglomerates.

In the mortar two amalgamated copper plates (amalgamated on one side) are inserted in such a way, beneath the feed, that the amalgamated sides face each other with a distance between them of 1 cm.

The coarse crushing by Blake crusher or Gates mills, is preceded by a hand picking in those mines which mine the thin conglomerate layers, and hence break barren material at the same time. These mines are, among others, the Robinson, Ferreira, New Riedfontain estate and Gold mine. The ore is wetted with water so that the white gold-bearing sulphides can be distinguished from the barren rock. By sorting out this barren material the stamp works and MacArthur Forrest process is relieved.

The extraction of gold depends very much on the manner of crushing. In the Transvaal, according to (Schmeisser), the sulphides are crushed finer than the quartzes, and they do not seem to proceed quite correctly in the crushing.

However in the Australian colonies, according to the same author (Die Goldfelder Australiens von Oberbergrath Schmeisser und Dr. Vogelsang, 1898), they have early recognized, that the great variety of gold ores need the most careful selection of method of treatment, embracing the crushing machinery as well as the actual method of extraction.

In the first ten years of gold mining in Australia, stamps were used almost exclusively. These were replaced in part by Krupp ball mills, Otis, Huntington and Pauclast mills. In stamping they use stamps up to 1,000 pounds with automatic feed, used in recent years in North America and South Africa.

In the Waihi & Silventon, Talisman, and Woodstock mines at

Karangahaki, dry stamping and cyaniding has replaced wet stamping and amalgamation. The ore is dried in large shaft-like furnaces, hewn in the mountains and then crushed in jaw crushers preparatory to stamping. By the application of an exhaustor the dust is almost entirely avoided in the mill buildings. The gold occurs finely divided in a quartz gangue.

The stamped ore is dumped directly into the tanks. The extraction is 91% gold and 48% silver, against 64% gold and 31% silver by the old amalgamation process.

At the Crown mine at the same place, after trial of the dry stamping, combined with the above process, wet stamping has been installed again with a special leaching treatment which gives satisfactory results. The quicker discharge in wet stamping giving increased capacity, and increased gold production, combined with the avoidance of drying the ore has made the cost of treatment considerably smaller.

According to Schmeisser, ball mills for dry crushing are preferable to stamps, because the first, with proper screens, permit the obtaining of a product of certain size, and the direct discharge of the crushed material, while in dry stamping a repeated falling back of the meal under the stamp takes place, with only an accidental discharge of the material through the screen, which decreases the capacity of the stamps considerably and also produces much slimes which are very detrimental in subsequent cyanidation.

This dry crushing could be improved upon, aside from the employment of ball mills, by the sorting of the dry pulp in Pape-Henneberg wind sifters, perhaps in combination with a Pape-Henneberg centrifugal dry separator. This would then be superior to the wet method at the Brown mine, because without sorting of the pulp from the stamps the extraction cannot be great.

In the Kalgoorlie district, where beside lack of water the working of the ores is made difficult by their clayey and earthy nature, dry crushing with wind sorting, system of Fried. Krupp, Grusomverk has been introduced as, *i. e.*, at the Norseman mine and the New Austral Company, as well as at the Hannaus Brownhill mine.

The dry crushed ore from the ball mill is sorted by means of air currents, in a simple way, into several classes of sands and dust.

The coarser gold in the coarser sands is extracted by pan amalgamation. This leached material as well as the sands and fine sharp dust which can be percolated by solution are treated in the

usual way by the MacArthur Forrest process. The very fine dust and clayey and earthy material, not readily subject to percolation are treated by the MacArthur process, with the addition of mechanical stirring appliances.

At the Hannaus Brownhill mine, a gold leaching mill is now being erected, after the combined pattern of Pape-Henneberg and Goepner-Diehl (No. 23, und f. d. Oesterr. Zeitschr., 1897, and No. 50 and 51 d. Bu. H. Zeitung, 1897), in which the Pape-Henneberg system of gradual dry crushing and improved wind sorting is employed.

The mill is not in complete running order and hence results cannot be had. The crushing machinery consists of two jaw crushers, two rolls, and three ball mills. Between each jaw crusher and rolls is placed a dry trommel, between the rolls and ball mill is placed a shaking screen which separates the products down to 1 mm. in size. The ball mills have a circumferential screen of 1 mm. mesh.

According to Schmeisser there were in operation in 1895: In Queensland, 129 stamp mills, with 1,836 stamps; 25 Huntington mills. In New South Wales, 281 stamp works, with 1157 stamps and 15 Huntington mills. In West Australia, 75 stamp mills, with 841 stamps and 2 Huntington mills. In the Kŏckar district of the southern Urals (No. 21, der. B. u. H. Zeit., 1898), the arrastra mill has been introduced, because it is more suitable for the crushing of the friable ore (quartz) and the soft country rock of the gold deposits than stamps. In 49 dressing mills there are only 5 stamp works, but 44 arrastras.

At the largest mines with the best arranged dressing plants, the ore is first crushed to nut size in Blake crushers, the crushed ore elevated by a bucket elevator to the third floor and dumped on a screen, whose coarse material is crushed by another machine to barley size. This product, with the fines from the above screen, is then crushed in Crom rolls down to a coarse meal size. The coarse from the screen in connection with these rolls is returned to them. Ventilators blow the dust from the screen through pipes into the dust room where it is completely sized by trommels. The dry dusts fall from the trommels into screw conveyors which load them into cars, these cars take them, in case they contain sufficient sulphides, to the roasters of the leaching division. Otherwise the dusts are stirred with water in tanks into a mud which

passes over amalgamation plates for taking out the free gold and then to Frue Vanners to concentrate the sulphides. These concentrates also go to the roasters.

Other mills treat the friable ore in a simpler way, in that it gets directly into the arrastras, from where the pulp goes over plates and then over Frue Vanners. Mercury is sometimes used in the arrastras. This dry crushing and sorting is similar to the Pape-Henneberg system, but is not as complete.

Classifying.

The classifying of the stamped pulp spitzkasten was first introduced in Hungary, but only in recent times.

v. Rittinger, however, recommended classifying in his book published as early as 1867 and says on page 477. "It would be of advantage to sort the pulp into equal falling grains in spitzkasten, before running it into the amalgamators, because then the amalgamator could be adjusted better to the ore; particularly would this be of advantage in collecting the fine gold. On account of the unwieldiness, of this arrangement it has not heretofore been made use of."

In the later stamp works at Siebenburgen, as *i. e.*, in the mill of the gold mine at Brad, built by the Grusomwerk, the pulp as it comes from the copper plates is led into a spitzkasten apparatus and is there classified into several kinds of sands and slimes, replacing the old collecting launders.

v. Rettinger, in the second appendix to his book, published in 1873, mentions a separator, which is used in the Washoe district (Comstock lode) in N. A. in treating the rich silver ores containing a little gold and serves to treat the pulp and amalgam. It is 9 feet in diameter and 3 feet high and has a stirring apparatus. "The purpose of the apparatus is to settle out the amalgam and mercury." A rake having 15 revolutions per minute serves as a discharge. Often the pulp flowing from this separator goes to a second separator of 6 to 12′ diameter called an agitator.

In the Transvaal according to Schmeisser, the pulp from the copper plates, in some mills goes directly into clearing basins, in others over fixed tables, which are covered with a coarse woolen cloth, in others again, without classification to Frue Vanners or Scoular tables.

The settlings of the basins, according to Schmeisser, contain 8 to 9 gr. gold.

In large basins or ponds the granular components, or sands, and the clayey fine material or slimes, are partly separated, the first settling in forward part of the basins and the latter in the rear part. At New Rietfontein estate there are two basins, one placed behind the other, the last at a higher elevation. The connection is so arranged that only the slimes reach the lower basin. At Randfontein and other gold mines this separation is aided by a spitzkasten placed above the first basin. The sands fall through the rising current of the spitzkasten while the lighter slimes are carried by current to the basin. Classifying has the disadvantage in its application to the cyanide process, that large basins are necessary and that the settlings must be brought back and rehandled. At Salisbury, New Heriot, City and Suburban, and Crown Reef it has therefore been tried to take the pulp from the copper plates directly to the tanks, passing it through spitzkasten above the tanks to take out the finest slimes. It is endeavored to influence the even settling of the material in the tanks by the use of hose, and by overflow holes arranged above each other, which drain the superfluous water and are closed as the pulp rises in the tanks. This method, however, requires careful watching and superintendence and skilled labor. Salisbury has discarded the method and returned to the old, because the extraction of gold was smaller.

The Butters-Mein automatic separator, known as a "distributor," is, according to Eissler (The Metallurgy of Gold, 1896, and No. 23 to 26 der Oesterr. Zeitschrift, 1897, and No. 50 d. B. u. H. Zeit., 1897), in use at the Princess works in the Transvaal; according to Schmeisser, experiments were being made with this device at the Rand Central Ore Reduction Co. works, when he was there.

This apparatus consists of a cast iron hollow column, having at the top a revolving spindle to which is fastened a conical funnel which has a number—8 to 16—radially arranged pipes. This mechanism, which is moved like the Segner water wheel, by the reaction of the pulp streams, is placed in the center of a tank filled with water. Each pipe has a certain length, so that the pipes distribute the pulp which flows to them from the funnel, over a series of concentric circles. The sands and part of the slimes sink down to the bottom, the fine slimes go off with the overflowing water. By the settling under water and the subsequent dumping of the mass into the leaching tanks a more even distribution of the gold contents are claimed, combined with the treatment of a greater amount of slimes in the same time.

In recent times the spitzkasten has also been introduced in the Transvaal for the classifying of the pulp as it comes from the stamps and also in reworking the old slimes and tailings. In the stamp mill of Langlaagte mine (No. 15 der Oesterr. Zeitschr. 1896) this pulp is separated into three classes, of which the finest class cannot be percolated by the solutions, but can be made adaptable by the application of burnt lime. According to No. 203, of the *South African Weekly*, three spitztrichter, or pointed boxes constructed of masonry are placed directly below the cement collecting boxes of the buddles, in the slime division of Crown Reef mine, for the treatment of the slimes produced daily. From these pointed boxes the slimes go by launder to a spitzlutte with six inverted cones, in which the fine sands which have escaped the spitztrichter, are separated, and then taken to three sand tanks (leaching vats). In this connection it may be mentioned, that this repeated separation (since any admixture of sands no matter how fine, increases the difficulty of treating slimes) does not alone increase the values of the sands, but also gives the slimes a particularly advantageous character for their further treatment.

In Australia, according to Schmeisser, the pulp from the plates is usually run over cloth for the collection of any escaped free gold and pyrite, and at some places is then led through launders for the separation of the sands. The pulp from these launders is allowed to run to waste.

"The tailings in many places are led directly into streams. Bonanzas have been thus fed into the Haurake Gulf, and into the Inangahua and other rivers. Those mills which could not discharge their tailings into rivers, but which on account of the scarcity of water, led them into clearing ponds, will return later with profit to the reworking of the tailings."

At the Tasmina Gold mine, spitzkasten have been introduced between the plates and Lührig plane tables, for the classification of pulp. In the working of telluride ores, spitzkasten are also used for careful concentration of the pulp.

A further and valuable improvement in the classification of dry crushed gold ores is the employment of the Pape-Henneberg wind sifter which will be first used in Australia, in the gold mill being constructed at the Hanaus Brownhill mine.

This wind sifter consists of a cylindrical or rectangular box, the walls of which, up to a certain height, consist of gauze, and the

interior of which is connected with an exhaustor. The finely crushed ore is fed into the apparatus from the top and slowly falls to the bottom. The bottom of the apparatus consists of several ring-shaped, or rectangular collecting troughs for the collection of the coarse, medium and fine sands. The finest particles or dust is taken out of the apparatus at the middle by the suction of the exhaustor, into a collecting basin having a dust filter, in which a separation of the meals, into coarse, fine, and impalpable dust takes place.

This wind sifting can be aided by the Pape-Henneberg centrifugal dry separator (No. 42, 1893, and No. 6, 1894, der Oesterr. Zeitschr., and No. 28 and 32 d. B. u. H. Zeit., 1896.) However, the centrifugal separator can have less collecting troughs than in former applications because it would treat only the medium and fine sands.

3. Concentration.

According to v. Rittinger, p. 490, the gold, finely disseminated in the ores, was formerly won as follows, in Hungary:

1. Running the pulp through sluices, and final concentration of the sands on tables.

2. Running the pulp through amalgamators.

3. A combination of the two methods, in that the pulp, after treatment in the amalgamators, is run through the sluices, and the sands collected thus with the escaped gold and mercury, which are further treated on tables.

If other finely-divided minerals carried gold, then sluices were used in the stamp room, and a gold table in the concentrating room. If the ore contained but little mineral beside the free gold, then buddles proper were used.

Later the continuous working percussion tables (system Rittinger) were advantageously employed for the preliminary concentration of gold bearing meals.

Expressed concisely, after starting amalgamation in the mortar or amalgamator, this was followed by sluices, the ordinary percussion table and the continuous percussion table for the coarser sands, and the buddle proper for the finest meal. The concentrates were usually rewashed on a small buddle, according to statements of the deceased oredressing inspector, v. Reytt of Pribram).

The continuous percussion table is particularly suited for concentrating the free gold, according to v. Reytt, because the gold is

separated cleanly in nice long strips, but the middle products and the tailings must be retreated on buddles to win the gold contained in mineral. v. Rittinger says, on p. 533 of his book, "As the finer meals and slimes can be well concentrated on rotating tables, the two last groups of continuous percussion tables (with arrangements for the classifying of slimes) can be replaced by these rotating tables, one rotating table can replace a group of two double percussion tables, as the capacity of a group of rotating tables is almost double that of a group of double percussion tables. Therefore, in place of the last two pairs of double percussion tables two rotating tables can be used, each of which is to treat a class of meal, and at the same time rework the middle products falling in the same class.

v. Rittinger had in mind, the rotating concave and convex, or inward and outward flow tables.

Recently the Bartsch round percussion table has been used in the dressing of auriferous ores in Hungary as *i. e.*, at Kremnitz (see No. 49, der Oesterr. Zeitschr., 1893, and No. 46 and 47 d. B. u. H. Zeit., 1895). Director Schwarz says of it: "Only fine slime or medium coarse meal should be sent to the table if these come from mills where coarse and granular products are made, but also coarse material, coarse meals up to ½ mm. size, if they come from mills where all the ore is crushed fine to pulp, as in gold mills, etc; with the last class the mineral always crushes finer than the gangue, and since the coarse tailings leave the table first, they do not have a disturbing influence on the enrichment of the fine mineral slimes. In gold mining the fineness of crushing changes continually, and the mineral is usually crushed so fine, that one is almost entirely dependent on table concentration, which permit of considerable variation. For these reasons, and because gold extraction is usually only profitable when the ore is crushed to slime that the Bartsch table is suitable for coarse meals as well as for the finest slimes. Of course, the table must be adjusted for each class of slime, which can easily be done as the percussion mechanism and the travelling speed can be readily changed."

In this connection it may be mentioned that the inclination of the Bartsch table cannot be regulated.

Beside this table, the Stein plane percussion table has been recently introduced in Hungary, by the Grusomverk as, *i. e.*, at the Muszari mine at Brád. The classes of sands and slimes made by the spitzkasten go continuously to the tables.

Here, as everywhere else, considerable gold was lost in the tailings of the tables. Director Köllner is hence employed at present in perfecting his gold mill, by concentrating all pulp in spitzkasten and on Lührig's compound tables.

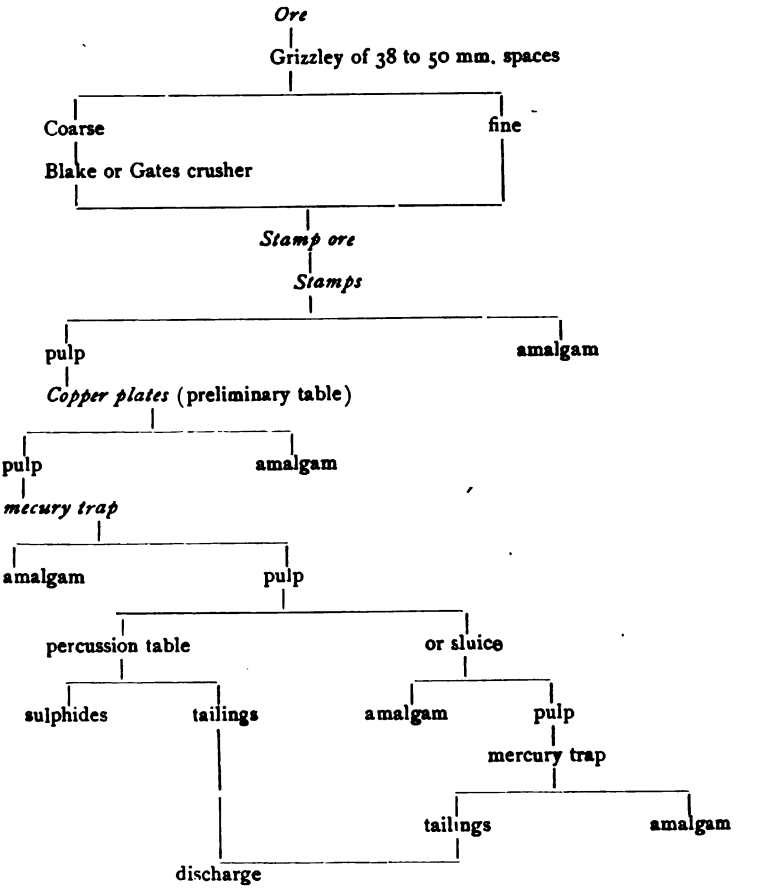
By this arrangement, the Hungarian gold mills will become the best in existence at present.

In California, according to Hammond, the pulp from the copper plates goes in part to jigs, which serve to concentrate the auriferous pyrites. The tailings from the jigs are led to sluices where some of the valuable material is won by various devices. The tailings are discharged from the sluices as worthless gangue. Aside from this several concentrators are in use in California, the most important of which are the Frue, Triumph, Golden Gate, Duncan and Hendy concentrators. The Triumph and Frue Vanners are at present the most useful. Both are, according to Hammond's view, excellent concentrators. Each one has particular advantages, and partisans among the mining men of California. The waste waters of the concentrators go to clearing basins outside of the mills, and the fine sulphides, often richer than the coarser concentrates, saved in this way.

For every battery of 5 stamps two concentrators are required. Three workmen can easily attend 16 of them in 24 hours. Valuable tailings from the concentrators are led over fixed long tables outside of the mill, and 100′ to 120′ long with an inclination of 1″ to 1¼″ per foot.

According to Professor Schulz, the auriferous pyrites are only saved within the last few years, on concentration in the whitewood district. The present and former method of treatment are represented by him in the accompanying diagram.

The first or preliminary table is fitted with amalgamated copper plates and is three meters long with a width equal to the mortars and an inclination of 164 mm. per meter. The pulp flows from two plates in the Golden Star mill, and Homestake mill and from four in the Highland mill, into a mercury trap and from this on to the percussion tables. Where as yet no percussion tables have been installed, the pulp flows from the mercury trap into a sluice lined with copper plates of 2.44 to 3 meters long and 4.57 mm. wide with an inclination of 82 mm. per meter. From here it goes to a second mercury trap, and from here to waste. The mercury traps consist of sluices specially arranged or of spitzkasten like devices.



The percussion table in use is the so-called Gilpin County Gilt Edge concentrator, named after Gilpin Co., Colorado. It is a continuous working length percussion table, similar to that in use at the end of the last century at Freiberg, after Mende system.

According to Schmeisser, the sulphides at the Pioneer gold mine in Johannesburg are concentrated on the Scoular tables, peculiar percussion tables with a side discharge of concentrates. This table however is not well adapted to the purpose, as many concentrates go off with the tailings, and the work it does, like that of the Frue Vanner used in the Transvaal, is very coarse.

At the Langlaagte estate in Johannesburg experiments were made in 1894, with the Linkenbach fixed round table for the con-

centration of fine slimes (No. 15 der Oesterr. Zeitschr., 1896). These slimes which previously could not be concentrated, were to be enriched on the Linkenbach tables, and their amount reduced to such an extent that they could be mixed with the coarser material of the pulp discharge from amalgamation to allow of cyanidation.

The experiments were made on material containing 6 to 8 g. gold per ton. They were classified in three spitzkasten into

1. Coarsest sort	15 g. gold
2. Medium "	9 g. "
3. Finest "	4.54 g. "
Discharge of the last spitzkasten . .	1.41 g. "

Class 1 and 2 were easily cyanidable. Class 3 was, however, not fit for percolation. This class was treated on a Linkenbach table which made the following products:

1. *Concentrates.*—27.2 per cent. of the material treated and containing 11.3 g. of gold per ton. 2. tailings—72.8 per cent. of material treated and containing 2.01 g. gold per ton.

"The concentrates freed from the clayey slimes could be mixed with the spitzkasten products 1 and 2, without offering difficulty to cyanidation. In the concentrates of the Linkenback table there were saved 68 per cent. of the gold contents of the slimes treated. Director Langemann of the Langlaagte Estate declared himself well satisfied with these results."

This rewashing could be dispensed with, because now the fine slimes are precipitated out of the pulp by burnt lime. They come down as a flocculent precipitate, in which condition the slimes are easily amenable to cyanidation, because they are very loose.

Of the various concentrating tables, the Stein plane table and the Lührig compound plane table would be preferable for the saving of the free gold and for the enrichment of the sulphides carrying gold, because these tables like the Rittinger table can make several products, varying but little in specific gravity. For instance galena and blende for gold from quartz could be sharply divided. These tables possess the same advantages as the Rittinger table, in that the inclination is adjustable, which is of particular importance for gold ores, because a greater quantity of barren materials must be separated out than in other ores.

4. Extraction.

An important improvement in aiding gold extraction by leaching, is the filter press for the filtering of the auriferous solution from the now barren pulp, introduced by the chemists Goepner and Dr. Diehl in the combination method of Pape-Hennberg and Goepner Diehl.

G. J. Bancroft, says in No. 8 of the *Eng. and Min. Journal*, 1898, in reference to goldmining in West Australia. "Up to the present the slimes could not be successfully treated on a large scale, but any ingenious improvement of a stirring or filter press method along which line experiments are now being made, will solve the problem."

Bancroft means by this the mill in course of construction at the Hanaus Brownhill mine, in which the filter press is to be employed in the above mentioned combination method.

The filter press, which has long since been in use in chemical factories for the separation of the liquids from the solid material, has also already been used in gold extraction, as far as known at La Plata and in Boulder County, Colorado. At the first place in the works of Pret, Trachtler & Co., the Johnson filter press is used to filter the liquid from the bromine process, after it has been allowed to settle out the slimes in the leaching barrels.

At the place in Boulder county already mentioned, the gold, according to C. C. Burger, is precipitated as sulphide of gold, by sulphuretted hydrogen, after treatment with sulphurous acid. The sulphide of gold is treated in a filter press to free it from solution, then dried, roasted and smelted.

Goeppner-Dieh employ the filter press at Hannaus Brownhill for the filtering of the solution from the treatment of the ore by cyanidation, because in this way it can be separated more completely and quickly than by the settling and ordinary draining in tanks, on account of the pressure employed. The pressed material is thoroughly washed after pressure has been applied.

Experiments on a small scale in the Goeppner chemical works at Hamburg have given good results, on the strength of which the system is being employed at Hannaus Brownhill mill.

Metallurgical engineer E. Bohne, at Fostent, recommends in No. 22, d. B. u. H. Zeit., 1898, in the treatment of slags from zinc ores with dilute sulphuric acid, the Korting stirring apparatus for the

mixing of the mass, and for the separation of the solution carrying the zinc and iron from the solids, a filter press like the Goeppner-Diehl, used to filter gold solutions.

Dr. Brand, in his paper, "Neuerungen im Gold probirwesen, ünd in der Verarbeitung von Golderzen," No. 25 d. Bu. H. Zeit., 1898, says: "For the leaching of the non-percolable slimes, filter presses have recently been introduced with success in West Australia, while formerly, in Witwatersrand, decantation had to be employed, with which however but little more than three-fourths of the gold could be saved, if the amount of solution was not to be increased enormously. After the success of this simple method (filter press) had been proven the first three plants were installed in West Australia, at the Norseman, the Australasia and New Austral mines, all of which have been very successful. Another large works at the Hannaus Brownhill mine at Kalgoorlie is almost ready to start up."

At these West Australian mines, the ores are crushed dry and are prepared for the cyaniding in wind sifting devices, being classified with sands, meals and dusts.

The preparation of the leaching ore, and the enrichment of gold concentrates before further treatment, is recommended by many experts, and considered to be of advantage. However, it is extremely difficult to generalize in the treatment of gold ores, because the occurrence at almost every mine is different. Some gold ores are difficult to amalgamate, some need roasting or heating, some an oxidation or mixing with mercury. Aside from this the occurrence of iron or arsenical pyrites, blende, chalcopyrite and galena makes the treatment difficult and causes loss of gold (v. Reytt.)

The oxidized ores are fairly easily treated by amalgamation, and it is mainly the sulphide ores which cause difficulty.

In the East Australian colonies and New Zealand, it was found as in North America, that with the increasing amounts of sulphides greater attention was required in concentrating these and that stamp mills and pan amalgamation were entirely unsuited for treatment. This holds good for those ores carrying very fine gold as well as those carrying auriferous sulphides. Even the presence of coarse gold presents difficulties, because it has been demonstrated after much experience, that repeated blows from the stamps rob it of its capacity for amalgamation, while at the same time it cannot be dis-

charged by the water on account of its high specific gravity. In most cases in West Australia the extraction by amalgamation is not sufficient, even with pure quartz ores, to dispense with subsequent cyanidation. This is to be observed in the ores of the Hannau's field and also in other occurrences. For treatment by stamp milling they are as unsuitable as possible, everything is against it.

1. The scarcity of water in the country.
2. The clayey character of the ore.
3. The fine dissemination of the gold.
4. With ores from depth, the presence to pyrite, arsenopyrite and above all telluride of gold (Dr. Brand).

Oberbegrath Schmeisser, says in reference of gold extraction in South Africa: "The endeavors of ore dressing experts must be in the direction of concentrating and enriching the slimes to such an extent that the refuse or tailings can be brought to the dump comparatively valueless, further this treatment must be economical and applicable to great quantities."

THE PARADOX OF THE PANTHEON.

By A. D. F. HAMLIN.

THIRD PAPER.

VI. (continued).

In the second paper of this series (published in the QUARTERLY for January) it was shown that between the structural design of the Pantheon at Rome and the panelling of the internal surface of its dome there exists an inherent contradiction of scheme. The supporting wall is a composition of eight parts, marked by eight vast niches or recesses, while the panelling consists of five rows of twenty-eight panels each. The vault is of solid brick, built with eight discharging arches over the eight niches of the wall below; and these cut through, and are cut into by, the panels of the two lower rows in a wholly accidental way. The system of construction alleged by Piranesi to have been observed by himself in 1756 or thereabout was illustrated and explained, and it was stated that M. Chédanne, who examined certain parts of the Pantheon with some care in 1892, discredits the Piranesi system, except as to the eight lower discharging arches, and declares the dome to be a homogeneous and simple massive shell of brick masonry above the eight discharging arches just mentioned. M. Chédanne was also represented as favoring the idea that the 140 panels, or coffers, had been formed at the outset in constructing the vault, the brick masonry having been laid up or moulded over a complete mould or pattern formed upon the centering in which the panels were shaped in relief. The writer endeavored briefly to expose the almost insurmountable mechanical difficulties in the way of such a procedure, and expressed his conviction that the panels had been *hewn* in the completed vault, possibly at once after its setting, quite as likely at a much later date. The arguments against this view, based on the aspect of the bricks in the small portions laid bare by M. Chédanne, and on the presence of bronze cramps in the centers of the panels, were declared to be inconclusive, and the opinion was expressed that the preponderance of evidence is in favor of the theory that the panels were cut from the completed vault.

This method of affecting the decoration of a vault appears so

strange and unusual as to demand, for its acceptance, other indications in its favor than mere probabilities based on the internal evidence of the building. What conclusions, if any, bearing on this question can we draw from the appearance of other buildings of like character?

It must be confessed that in the present state of our knowledge such evidence is inconclusive. A careful and systematic examination of many of the important vaults or fragments of vaults belonging to the period from the time of Hadrian to that of Constantine has yet to be made. Only by such an examination can the true history and chronology of panelled vault-decoration be worked out. If it should appear that all or nearly all the brick or concrete vaults of the earlier Imperial structures were internally smooth, with decorations in color or in low relief upon stucco, and that with the maturing years and close of the second century

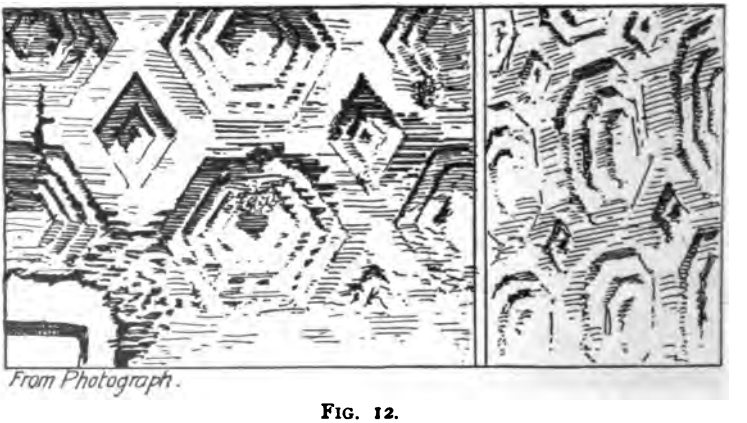


FIG. 12.

A. D. panelling became more general, and from Caracalla to Constantine, almost universal, it would be easy to understand how Septimius Severus or Caracalla, in the course of their alterations and improvements of the Pantheon, should have determined to panel a vault originally smooth or decorated in stucco. The carrying out of this determination presents no mechanical difficulties whatever. It is, indeed, easier to hew out a panel in the brickwork than to cut each brick separately for its place upon a complicated mould. This supposition would further explain why the upper part was left smooth, since it is harder and more trying

to cut the panels from directly overhead—from a nearly horizontal overhanging surface—than from the oblique or more nearly vertical portions of the vault.

So far as the available documents go, it would appear that while smooth vaults continued to be used through the whole Imperial age (Torre dei Schiavi, Tomba delle Tosse, "Temple of Minerva Medica"), panelled vaulting is more frequent and elaborate in the later than in the earlier examples. The most conspicuous instances of its use are in the Baths of Caracalla (211 A. D.) and the Basilica of Maxentius and Constantine (*cir.* 324 A. D.). Fig. 12 * gives details from a photograph of a part of the segmental half dome of one of the recesses of the great frigidarium of the above-mentioned baths. The vaulting is executed in solid brick in continuous horizontal courses, cut into by very sharply-formed and deep panels, hexagonal and lozenge-shaped in one instance, octagonal and square in the other. The resemblance of these panels, with their successive steppings, to those of the Pantheon, is manifest at a glance. I cannot believe that they were formed upon a wooden mould. They present every appearance of having been hewn in, or from, the solid masonry. The conviction that this was the method of their making is strengthened by the evidence of the panelled vaulting of the lateral recesses of the Basilica of Maxentius and Constantine (Fig. 13). Here the builder employed brick ribs, which separate the vertical rows of octagonal panels, but which are cut into by the smaller intermediate square panels of the pattern. M. Choisy has imagined an ingenious theory of the way this was managed. He supposes that a deep rectangular notch was left in the rib at each place where these small square panels occur, and that these little panels were formed, like the larger octagons in the concrete fillings between the ribs, by means of patterns or moulds of wood (Fig. 14). But, aside from the fact that this rectangular notching of the ribs is a matter of supposition only, since nowhere in the ruins of the basilica so far as I know, is the real structure of the ribs laid bare, it would seem that M. Choisy's own drawings contradict this supposition. In the brick rib as

* In the difficult task of interpreting a photograph by a line drawing, horizontal lines were used to indicate the courses of brick where they show in the original. To suggest the shading, horizontal lines were also used, which to some extent confuses the indication of the masonry; but as *all* the brick courses are horizontal this is not a serious defect so far as present purposes are concerned.

shown in Fig. 14 it is obvious that the notch is everywhere rectangular; but in Fig. 13, showing a portion of the completed vault, the bricks are shown coming down completely to the edges of the small sunk panels, which cut off the abutting bricks everywhere by planes at 45°. Obviously both representations cannot be correct. If Fig. 13 is correct, the small sunk panel could only have been executed by the axe or chisel after the completion of the brick and concrete vault. If Fig. 14 is correct, how did M. Choisy come to make such a mistake in the drawing of Fig. 13? The text offers no explanation, and the fact that such a contradiction

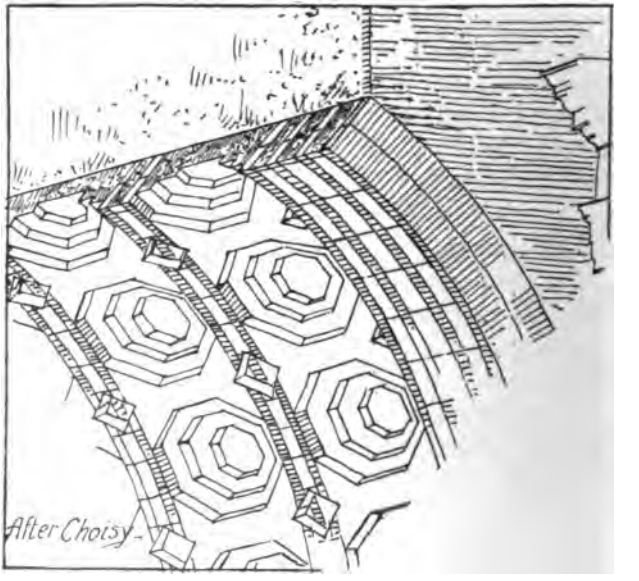


FIG. 13.

should pass unnoticed by its author makes the accuracy of his observation of details in this case somewhat doubtful. All the other drawings I have seen, and my own recollection of the huge fallen fragment of vaulting in one of these recesses, agree with Fig. 13 in representing the small panels as cutting directly into the brickwork of the rib. It would be very interesting to know, and it affords a good subject for investigation, whether this same vaulting contains other brickwork than the vertical divisional ribs shown in M. Choisy's drawings, and whether these, if existing, are cut into by the recessed panels, and in what manner

To sum up the conclusions which appear most rational, taking into account the present unsatisfactory character of the evidence at hand, or at least its lack of final conclusiveness, it would seem probable that the dome of the Pantheon as constructed in the time of Hadrian was internally a smooth vault, as its upper part always remained, and as many great vaults often were, *e. g.*, the great vault of the Tepidarium of Diocletian's Baths, now the nave of S. Maria degli Angeli. At some date subsequent to its completion, and very probably in the time of Septimius Severus, who rebuilt the great portico of the temple, or of Caracalla, it

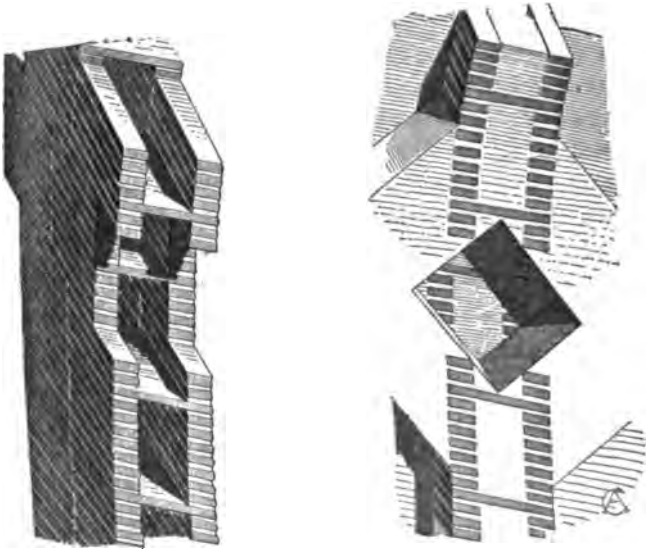


FIG. 14. (From Choisy, "L'Art de Bâtirchez les Romains.")

would appear that the emperor, desiring to embellish the dome and to replace its faded or ineffective stucco decoration with something more permanent and dignified, caused the existing panels to be hewn as a part of his work of general restoration and improvement. Owing to the difficulty and danger of working from overhead in the nearly flat central field of the dome this work was confined to the lower three-quarters of its surface. It was a work easily executed when once the scaffolding was erected. No indications of the internal structure, discharging-arches or ribs appeared upon the stuccoed surface of the dome. The designer concerned himself,

therefore, with only two problems—to secure an adequate scale in his work and to arrange so that the panels should center over the four axial niches of the building. The resultant of these two considerations was the adoption of a scale or spacing giving six panels intermediate between those centered on the axes of the building. The panels were marked out on the plastered surface and the cutting begun, the hewing away of portions of the discharging-arches of the dome being a relatively unimportant incident of the work. The beveling of the lower reveal of each sinkage of the panels was a very simple detail of the cutting, although it would have caused infinite labor and trouble to execute upon a mould as suggested by M. Chédanne. When the hewing was thus completed the whole was once more stuccoed, mouldings were run in the stucco of the edges of the 140 panels, the central rosettes and adornments of gilded bronze were added and the work was complete.

The final proof or disproof of this theory must rest upon further and more minute investigation than has yet been possible, both of the Pantheon itself—to the unravelling of whose complicated history M. Chédanne has made so important a contribution —and of other vaulted structures of the Roman Imperial epoch. The Piranesi system must be finally vindicated or disproved by a more complete examination of the dome than has so far been undertaken. The brickwork of this and other monuments must be examined for technical evidence as to its having been hewn or laid up to a mould. It is to be hoped that the labors of the Italian government, whose Direzione Generale delle Antichità watches with such zealous and intelligent guardianship over its priceless archæological possessions, and the investigations of archæologists and students, both Italian and foreign, to whom the government shows such considerate hospitality—a hospitality of which I have myself had delightful experience—may at no distant date finally and authoritatively elucidate the paradox of the Pantheon.

[Contribution from the Havemeyer Laboratories, Columbia University, No. 30.]

NOTES ON THE FERROCYANIDE TITRATION OF ZINC.

BY EDMUND H. MILLER AND E. J. HALL.

The experiments recorded in this article were undertaken to find out the influence of hydrochloric acid and those salts, most likely to be present, on the estimation of zinc by titration with potassium ferrocyanide using uranium acetate as an indicator.

The solutions used were:

1. Potassium ferrocyanide, 43.2 grams of the crystallized salt per liter.

2. Zinc chloride, 12 grams (approximately) per liter, containing 40 cubic centimeters of hydrochloric acid, 1.2 specific gravity.

3. Uranium acetate, a saturated aqueous solution.

The method and conditions of titration were as follows: 50 cubic centimeters of the zinc chloride solution, containing 2 cubic centimeters of hydrochloric acid, were measured into a beaker by a pipette; the salt or acid, whose influence was to be tested, added; then water to bring the total volume to 200 cubic centimeters. The solution was then heated to boiling and after stirring vigorously, titrated. The conditions for titration so far as volume and temperature are concerned were in all cases 200 cubic centimeters and 80°–90° C. The end point was determined in the usual way, using drops of uranium acetate on either sized paper or on a porcelain tile. A light but distinct brownish flesh color was taken as the end. The allowance necessary to turn the indicator in the presence of two cubic centimeters of hydrochloric acid was found to be 0.3 c.c. on paper and 0.35 c.c. on porcelain. This difference is one of individual eyesight and is given to explain why the quantities subtracted are not uniform.

EFFECT OF HYDROCHLORIC ACID.

2 c.c.	HCl	1.2	Sp. Gr.	required	0.35 c.c.	$K_4Fe(CN)_6$ solution.
4 c.c.	"	"	"		0.45 c.c.	" "
6 c.c.	"	"	"		0.60 c.c.	" "
8 c.c.	"	"	"		0.75 c.c.	" "
10 c.c.	"	"	"		0.85 c c.	" "

Each result is the average of three determinations made on

porcelain. More hydrochloric acid exerts such a solvent action on the uranium ferrocyanide as to render the indicator unreliable.

50 c.c.	$ZnCl_2$	solution	containing	2 c.c.	HCl	required	27.65 c.c.
"	"	"	"	4 c.c.	"	"	27.70 c.c.
"	"	"	"	6 c.c.	"	"	27.80 c.c.
"	"	"	"	8 c.c.	"	"	27.90 c.c.
"	"	"	"	10 c.c.	"	"	28.00 c.c.
"	"	"	"	12 c.c.	"	"	28.10 c.c.
"	"	"	"	14 c.c.	"	"	28 20 c.c.

Correcting by blank test we get that 50 c.c. of the zinc chloride solution containing 2 c.c. of hydrochloric acid requires 27.3 c.c. of the ferrocyanide solution. This is the result of six determinations and is the value used throughout. The other results are averages of two or three tests. By subtracting 27.3 from the values given we get the amounts required for the indicator in the presence of zinc to be, for 4 c.c. HCl, 0.4 c.c.; 6 c.c. HCl, 0.5 c.c.; 8 c.c. HCl, 0.6 c.c.; 10 c.c. HCl, 0.7 c.c.; 12 c.c. HCl, 0.8 c.c.; 14 c c. HCl, 0.9 c.c. Determinations made on paper gave slightly lower results: 6 c.c. HCl, 0.45 c.c.; 8 c.c. HCl, 0.5 c.c.; 10 c.c. HCl, 0.6 c.c.

These results show the great influence of hydrochloric acid on the indicator and that it is diminished by the presence of zinc ferrocyanide.

Effect of Magnesium Sulphate.

Moldenhauer* states that in the titration of zinc by potassium ferrocyanide in an ammoniacal solution, magnesium interferes, as the ferrocyanide is not readily soluble in ammonia. The following tests were made to ascertain whether it had any influence in an acid solution. To 50 c.c. of the zinc chloride solution containing 2 c.c. of hydrochloric acid, different quantities of MgO as sulphate were added and the solution titrated under the standard conditions

0.01	gram	MgO	required	27.65	c.c.	corrected	27.35 c.c.
0.10	"	"	"	27.70	c.c.	"	27.40 c.c.
1.00	"	"	"	27.70	c.c.	"	27.40 c.c.

In order to test the solvent effect of magnesium sulphate on the indicator, two portions of crystallized magnesium sulphate 6.111 grams each (1 gram MgO) were dissolved and titrated in the presence of 2 c.c. of HCl. They each required 0.6 c.c.

* *Chem. Zeit.*, No. 14, 1891.

Assuming that the solvent action is less in the presence of zinc, as is the case with hydrochloric acid, we conclude that the interference of magnesium is negligible in an acid solution and is due to a slight solvent action on the indicator, not to the formation of magnesium ferrocyanide.

Effect of Calcium Chloride.

The following weights of calcium chloride were added to portions of zinc chloride solution as described under magnesium sulphate:

0.05 gram $CaCl_2$	required	27.65 c.c.	corrected	27.35 c.c.
0.50 " "	"	27.85 c.c.	"	27.55 c.c.
5.00 " "	"	28.00 c.c.	"	27.70 c.c.

Our experiments accord with the statement by Low,* that calcium acetate exerts a solvent action on uranium ferrocyanide and so interferes in the lead titration by potassium ferrocyanide.

Effect of Ammonium Chloride.

As small amounts of iron are usually separated from zinc, in the analysis of ores, by the ammonia in the presence of a large amount of ammonium chloride, the effect of this salt is of importance. To 50 c.c. of zinc chloride solution containing 2 c.c. of hydrochloric acid the following weights of ammonium chloride were added before titration under the usual conditions:

5 grams NH_4Cl	required	27.85 c.c.	corrected	27.55 c.c.
10 " "	"	27.90 c.c.	"	27.60 c c.
20 " "	"	28.00 c.c.	"	27.70 c.c.

Tests were next made to see whether the error was due to a solvent action on the indicator. Ten grams NH_4Cl added to 2 c.c. of HCl and titrated as usual gave a sharp end point at 0.3 c.c.; 20 grams, the same result, 0.3 c.c., showing that the effect of large quantities of ammonium chloride was to sharpen the end point.† That the influence of ammonium chloride is on the zinc ferrocyanide and not on the indicator is shown by the marked difference in the appearance of the solution titrated when ammonium chloride is present. The precipitate is greenish white and flocculent, at the beginning of the titration, near the end, when about 0.3 c.c. more is required, as indicated by uranium acetate, there is a sudden

* *J. Am. Chem. Soc.*, 1893, p. 552.

† Compare Beringer, Text-Book of Assaying, p. 221.

change, the precipitate becomes brownish white and the green color entirely disappears.

To confirm our results the following tests were made:

NH_4Cl	$ZnCl_2$ Solution.	HCl.	Change in Ppt.	Vol. used.	Corrected.
0	= 50 c.c.	2 c.c.	none	27.65 c.c.	27.30 c.c.
5	"	"	27.5 c.c.	27.70 c.c.	27.40 c.c.
10	"	"	27.4 (about)	27.80 c.c.	27.50 c.c.
10	"	"	27.5 c.c.	27.70 c.c.	27.40 c.c.
20	"	"	27.6 c.c.	27.85 c.c.	27.55 c.c.

This change apparently coincides with the complete conversion of the zinc to $K_2Zn_3Fe_2(CN)_{12}$. It does not take place when the titration is made in an ammoniacal solution, where the normal zinc ferrocyanide, $Zn_2Fe(CN)_6$, is formed.

Effect of Aluminium Sulphate.

The removal of copper from zinc ores can be readily effected by aluminium foil in a sulphuric acid solution,* but the uncertainty of the end reaction with uranium acetate suggested the following experiments. To 50 c.c. portions of the zinc chloride solution containing 2 c.c. of HCl, 0.20 gram of Al_2O_3 was added in the form of crystallized aluminium sulphate. The amount of hydrochloric acid was varied.

Al_2O_3.	HCl.	Volume used.	Corrected.
0.20 gram.	2 c.c.	22.80 c.c.	22.50 c.c.
"	3 c.c.	22.30 c.c.	21.95 c.c.
"	5 c.c.	26.80 c.c.	26.40 c.c.
"	7 c.c.	28.40 c.c.	27.95 c.c.
"	7 c.c.	27.75 c.c.	27.35 c.c.
"	7 c.c.	28.60 c.c.	28.15 c.c.
"	7 c.c.	28.00 c.c.	27.55 c.c.

The influence of aluminium sulphate is very marked, giving low results with small amounts of acid and in all cases irregular results. In the presence of this salt it is impossible to ascertain the end point with certainty as the brown color appears very gradually and is never distinct.

Experiments were made with no zinc present which gave with 2 c.c. and with 6 c.c. of HCl, 0.7 c.c. as the allowance for the indicator, but the color was not satisfactory.

When potassium ferrocyanide is added to a neutral solution of

* Furman, Manual of Practical Assaying, page 209.

aluminium sulphate, the aluminium being in excess, and boiled, a white precipitate is formed similar in appearance to zinc ferrocyanide; a drop of the solution containing this precipitate gives a brown color with uranium acetate. When hydrochloric acid is added to the solution containing the precipitate, the reaction with uranium acetate is checked. A precipitate is formed on heating a solution of aluminium sulphate with potassium ferrocyanide even in the presence of considerable hydrochloric acid.

The interference of aluminium with the indicator seems analogous to that of manganese * and is sufficiently marked to render its use for removing copper very objectionable.

Effect of Lead Chloride.

If we discard the use of aluminium to precipitate copper we must go back to lead as the best substitute. The following experiments were made to determine how much hydrochloric acid is necessary to prevent any precipitation of lead ferrocyanide. The titrations were performed under the usual conditions, the lead being added as chloride to the zinc solution.

Pb.	HCl.	Volume required.	Corrected.
0.005 gram.	2 c.c.	27.70 c.c.	27.40 c.c.
0.01 "	"	27.75 c.c.	27.45 c.c.
0.02 "	"	27.80 c.c.	27.50 c.c.
0.04 "	"	27.90 c.c.	27.60 c.c.
0.08 "	"	28.00 c.c.	27.70 c.c.
0.16 "	"	28.05 c.c.	27.75 c.c.
0.32 "	"	29.60 c.c.	29.30 c.c.
0.64 "	"	37.10 c.c.	36.80 c.c.

Two cubic centimeters of hydrochloric acid is insufficient for more than a trace of lead.

Pb.	HCl.	Volume required.	Corrected.
0.32 gram.	4 c.c.	27.90 c.c.	27.55 c.c.
0.64 "	4 c.c.	29.00 c.c.	28.65 c.c.
0.32 "	6 c.c.	27.85 c.c.	27.40 c.c.
0.64 "	6 c.c.	27.90 c.c.	27.45 c.c.
0.32 "	8 c.c.	27.95 c.c.	27.45 c.c.
0.64 "	8 c.c.	27.95 c.c.	27.45 c.c.
0.32 "	10 c.c.	28.00 c.c.	27.40 c.c.
0.64 "	10 c.c.	28.05 c.c.	27.45 c.c.

This shows that 6 c.c. of hydrochloric acid, 1.2 sp. gr. will pre-

* Stone, *J. Am. Chem. Soc.*, Vol. 15, p. 473, 1895.

vent any interference due to lead. As Comey's Dictionary of Solubilities states that lead ferrocyanide is soluble in sodium citrate, we tried this salt to prevent the precipitation of the lead, but found that while it prevented the precipitation of lead it had such a solvent action on uranium ferrocyanide that it could not be used. Citric acid was also tried without satisfactory results.

Effect of Bismuth Nitrate.

Small quantities of bismuth as nitrate were added to the zinc chloride solution and titrated as usual.

Bi.	HCl.	Volume required.	Corrected.
0.005 gram.	2 c.c.	27.80 c.c.	27.50 c.c.
0.01 "	12 c.c.	28.00 c.c.	27.40 c.c.
0.02 "	12 c.c.	28.00 c.c.	27.40 c.c.
0.04 "	12 c.c.	28.00 c.c.	27.40 c.c.

Small amounts of bismuth have no influence.

Effect of Antimony Trichloride.

0.10 gram of antimony trichloride was added to the zinc chloride with sufficient acid to prevent the precipitation of basic salts.

$SbCl_3$.	HCl.	Volume required.	Corrected.
0.10 gram.	8 c.c.	28.2 c.c.	27.7 c.c.
0.10 gram.	10 c.c.	28.4 c.c.	27.8 c.c.

Antimony interferes with the titration.

We conclude from these experiments:

1. That the amount to be subtracted as shown by a blank test is often greater than the excess required in the actual titration.

2. That salts, such as calcium chloride, sodium citrate and acids, notably hydrochloric, retard the end reaction by their solvent action on uranium ferrocyanide.

3. That ammonium chloride, not exceeding ten grams, does not interfere with the accuracy of the method, but has some (unknown) effect on the zinc ferrocyanide.

4. That the presence of considerable quantities of aluminium sulphate, such as would be present if copper were removed by aluminium foil, renders the results unreliable.

5. That six cubic centimeters of concentrated hydrochloric acid is sufficient to prevent any interference by lead.

6. That antimony gives high results, while small quantities of bismuth have no influence.

Havemeyer Hall, April 2, 1900.

FREDERICK MORGAN WATSON.

On the 18th day of February last, at Cannes, France, occurred the death, at the age of thirty-four, of Frederick Morgan Watson, a graduate of our School of Mines and one of the ablest and most prominent of the American mining engineers engaged in the South African gold fields.

Mr. Watson, born in Pennsylvania in 1866, was the son of the late Albert Watson. During most of his boyhood years his family lived in Cleveland, Ohio, where he received his preparatory training at the Central High School. In 1885 he graduated, at the age of only nineteen, from the School of Mines, Columbia College, and immediately afterward went to Mexico. His first position was that of assayer and surveyor to La Noria Mining Co., in the State of Zacatecas. Soon afterward he was engaged by the neighboring Sombrerete Mining Co., in whose employ he remained until 1889, finally occupying the post of mill superintendent. While here he took part in an extensive series of investigations and tests for the purpose of determining the proper method of treatment for the rebellious and difficult silver ores occurring in this mine. As a result a large mill was built for roasting and leaching by the Russell process.

In 1890 Mr. Watson went to Peru, where he joined a party of English and American mining engineers in the employ of the Peruvian Exploration Syndicate, Ltd. This syndicate was, in a measure, related to the Peruvian Corporation, formed under the well-known "Grace Contract" by the foreign bond-holders of the railways of Peru. After about a year occupied in examining and reporting upon a number of silver and gold mines, he was engaged as mining engineer by Messrs. Frecheville Bros., of London. Much of his time during this period was spent at the tin mines of Cornwall. In 1892 he returned to Peru as manager of the Compania Andes, a large mining and smelting concern at Casapalca, on the Oroya Railroad. Here he remained three years, and by his energetic and skillful management achieved a marked success. But, owing to the extremely trying climate at this great altitude—about 14,000 feet above sea-level—it is probable that his health

was seriously undermined. Before leaving Peru he undertook a long exploring trip through the interesting mining regions east of the summit of the Andes, and along the head-waters of the Amazon River.

About the beginning of 1895 Mr. Watson went out to South Africa, under engagement with the Consolidated Gold Fields of South Africa, Ltd., with which company he remained to the time of his death. After spending several months in studying the Rand deposits, and becoming familiar with the conditions and methods of mining of the district, his headquarters were transferred to Bulawayo, Rhodesia. Here he was assigned the task of investigating the numerous Rhodesian holdings of the company, in Matabele- and Mashonaland, and in exploring new mining districts regarding which but little information was available. From Bulawayo he made a number of trips, covering a large area of country very difficult of access, from near the Zambezi River on the north to the lower part of Matabeleland. He was one of the first engineers to make a systematic examination of these mining fields, which, owing to numerous traces of ancient workings, were supposed to have an important future.

Mr. Watson's efficient work in Rhodesia led to his appointment, in March, 1896, as Acting General Manager of the Simmer and Jack Proprietary Mines, Ltd., at Germiston, a suburb of Johannesburg. These mines were then among the largest on the Rand, and the most important of the Consolidated Gold Fields' properties. His title was soon changed to that of General Manager of this huge concern, employing in the latter part of 1896, 558 white men and 3800 Kaffirs. A new 280-stamp mill was completed in 1898, giving a total crushing capacity for the mine from 320 stamps, of about 1500 tons per day, and requiring a force of between 5000 and 6000 men, white and black. In March, 1899, he resigned his managership of the Simmer and Jack mines, and was appointed Joint Manager of the entire mining interests of the Consolidated Gold Fields. His duties covered the technical part of the work, while his colleague had charge of the general company business.

During his three years' control of the Simmer and Jack mines Mr. Watson raised the property to the position of the largest producer among the great mines of the Rand. One could hardly exaggerate the close, unremitting attention to details required to bring about this result in the face of the arduous conditions, and

the difficulties and obstacles to progress, resulting from the unfortunate attitude of the Boer government toward the mining industry. An enormous amount of underground development had to be pushed forward rapidly to prepare for the increased production demanded by the large new mill and other extensive surface plant erected during this period; for it must be remembered that the bulk of the output came from a reef but little more than three feet thick. Soon after his establishment at Johannesburg, Mr. Watson had attained an enviable reputation for all-around efficiency as a mining man. His success was the result of a strong will and natural ability, on the one hand, and on the other an unusual capacity for well-directed work. His habit of mind was to take nothing for granted, and to delegate to subordinates nothing which could be better done by himself. Every part of the work, underground and surface, was under his personal scrutiny. Close study of details was indeed necessary to attain success in operating a large, comparatively low grade property, with many avenues of possible waste.

Perhaps the most trying period of Mr. Watson's career came after he had been made Joint Manager of the Gold Fields. At the outbreak of the Boer war, although his health had begun to fail, he considered it imperative to remain at his post even after the departure of all the English, and nearly all of the prominent American engineers of the district. His colleague had been compelled to leave six weeks before. During the last two weeks of Mr. Watson's stay, just before and after the war opened, the Uitlanders were put under martial law. Government proclamations, often contradictory, were issued daily. Finally it became no longer possible to keep the mines going. An order was issued by the Boers for swearing in all Americans as special constables, which was probably only a euphemism to cover the intention of the authorities to send them to the front. Four days after active hostilities began what was left of the Gold Fields' staff with difficulty succeeded in getting away to the coast, having protected the Company's interests as long as it was possible. While waiting for a steamer at Delagoa Bay, Mr. Watson took the fever, and after a hard trip arrived at Cape Town in a serious condition. Rapid consumption had set in, and he lived but little more than two months after reaching England.

Passing away at the age of only thirty-four, an age at which

many men are but just beginning their serious life-work, he had already won for himself a high and influential position in his profession. He was an engineer of marked ability, a thorough miner on both the technical and administrative side, kind and genial as a man, and a steadfast friend. His death is deplored not only by his personal friends, but by a wide circle of business associates.

ROBERT PEELE.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

By ELWYN WALLER.

Use of Hydrogen Peroxide. Friedheim and Brühl (*Zts. Anal. Chem.*, XXXVIII., 681). The separations with this reagent, described by Jaunasch and his pupils, are practically all incomplete, the apparently correct results having resulted from a compensation of errors.

Standardizing Alkalimetric and Acidimetric Solutions. Puckner (*Pharm. Arch.*, I., 172). The use of crystallized $H_2C_2O_4$ is disapproved. The author prefers to weigh out 10 c.c. of (approximately) normal H_2SO_4, add strong ammonia in excess, evaporate (in a flask) dry at 65 to 80° C. and weigh the $(NH_4)_2SO_4$. Standard ze mineral acids by use of weighed amounts of borax using methyl orange as indicator. The difficulty with this is the absence of a sharp color change at the end. Na_2CO_3 may be used if made by heating 20 gms. of $NaHCO_3$ for 10 minutes in a porcelain dish over the full flame of a burner. The material while hot is transferred to tubes in lots of 1.5 to 2 gms. and well corked up. Each tube is only opened when needed for use, being afterward recorked and weighed.

Standardizing Alkalimetric Solutions. Masson (*Ch. News*, LXXXI., 73). To obtain normal HCl an approximately correct solution is made up. Pieces of Iceland spar of about 2 to 3 gms. each are weighed out in separate beakers. Into each beaker is run 20 c.c. of the HCl solution to be standardized. The beakers (covered) are set aside for a few hours until the active effervescence has passed off when they are boiled or kept near the boiling point for an hour. Decant off, wash well, dry and weigh. If the HCl is normal the loss is exactly 1 gm.

Indicators for Alkalimetry (*Zts. Anal. Chem.*, XXXVIII., 273). The Association of Bavarian Industrial Chemists divide indicators into groups as follows:

Group 1. (Sensitive to alkalies) (*a*) Tropæolin oo.
(*b*) Methyl-ethyl orange, Dimethyl-amido-azo-benzene.
(*c*) Congo red, Benzo-purpurin, ideosin, cochineal.
(*d*) Lacmoid.

Group 2. (*a*) Fluoresceïn.
(*b*) Alizarin, Archil, Hæmatoxylin, Gallein.
(*c*) Litmus.
(*d*) *p*-Nitrophenol, Guiacum tincture.
(*e*) Rosolic acid.

Group 3. (Sensitive to acids) (*a*) Tropaeolin ooo.
(*b*) Phenolphthalein, Turmeric, Curcumin W. Flavescin.
(*c*) *a*-Naphtholbenzeïn.
(*d*) Porrier's blue, C_4B.

In each group, the first named members are the more sensitive to alkalies. The relative strength of acidity may be found by comparative titrations with indicators of the different groups. In a homologous series of

organic acids containing the same number of carboxyl groups, the strength of acidity decreases with increase in molecular weight. Where the molecular weight is approximately the same, the strength of acidity increases with increase in the number of OH groups.

Weak bases when neutralized by strong acids are likely to show an acid reaction, and per contra, weak acids when neutralized by strong bases may show alkaline. In case of considerable dilution these phenomena may be aggravated, so that the degree of dilution at which the solution has been standardized, is an element to be taken into consideration.

Alkalies in Waters. Bohlig (*Zts. Anal. Chem.*, XXXVIII., 431). 500 c.c. of the water are evaporated rapidly, then H_2SO_4 added, and the mixture heated to fumes. The residue is then rinsed into a flask, $BaCO_3$ added, and CO_2 passed in. After filtering, the filtrate is evaporated to dryness, and the residue treated with 50 c.c. of a mixture of equal parts of alcohol and water. Under these conditions only the alkaline carbonates are dissolved out. Titrate with N/10 HCl to get total alkalinity, and determine K by $PtCl_4$ precipitation, calculating Na by difference.

Potassium Estimation. Bolm (*Zts. Anal. Chem.*, XXXVIII., 348) dissolves the (washed with alcohol) K_2PtCl_6 in hot water, and precipitates out Pt by warming with Hg in a glass or porcelain dish, Bonjean (*Bull. Soc. Chem.* [3], XXI., 691) separates Pt from the precipitate by use of metallic Mg.

Volumetric for Magnesia. Handy (*J. Am. Chem. Soc.*, XXII., 31). In the alkalimetric method (dissolving $MgNH_4PO_4$ in standard acid and titrating back) for the removal of the ammonia of the wash water, the author finds that by opening up the paper, and drying at 50 to 60° C. (not higher) until the filters have dried about half an inch from the margin, the ammonia is practically removed, and the operation may then be conducted in the manner described in Sutton's Volumetric Analysis.

Volumetric for Magnesium. Meade (*J. Am. Chem. Soc.*, XXI., 746). The process consists in precipitating as $MgNH_4AsO_4$, and determining As in the precipitate by use of KI and standard $Na_2S_2O_3$.

The details are as follows: The solution should not contain too great an excess of NH_4Cl or $(NH_4)_2C_2O_4$. Pour into an Erlenmeyer flask, add one-third its volume of strong ammonia and 50 c.c. Na_2HAsO_4 solution. Cork tightly and shake vigorously (10 minutes). Allow to settle somewhat, filter, and wash with diluted ammonia (1 to 3 of H_2O) until the washings give no reaction for As. Avoid using too much washing solution. Dissolve the precipitate in HCl (1 : 1) running the acid solution back into the original flask, cool, if not already so, and add 3 to 5 gms. KI (free from KIO_3). Allow to stand a few minutes. Under these conditions the As reduces to the -ous form with liberation of I. Then titrate with standard $Na_2S_2O_3$, finishing with starch indicator in the usual manner.

The Na_2HAsO_4 solution is made by dissolving 12.29 gms. pure As_2O_3 in HNO_3, evaporating to dryness on a water bath, neutralizing with Na_2CO_3 and diluting to a litre. Each c.c. = 0.005 gm. MgO.

Alumina-Direct Precipitation. Hess and Campbell (*J. Am. Chem. Soc.*, XXI., 776). Phenylhydrazine was found to precipitate $Al_2(OH)_6$

completely from its solutions, the precipitate being free from iron, although if P_2O_5 is present, the precipitate will contain $AlPO_4$. The chloride solution is first nearly neutralized with ammonia. To the hot solution is then added strong solution of NH_4HSO_3, and after that neutralization is completed by addition of phenylhydrazine, a few c.c. at a time to complete precipitation. Then filter and wash with warm water containing a little phenylhydrazine bisulphite. After drying the precipitate, bring slowly up to the temperature of ignition, finally igniting at bright red. $Cr_2(OH)_6$ can be separated from Fe, Ca, Mg, Mn, Co. and Ni by the same treatment. In the filtrate Fe is best separated by $(NH_4)_2S$.

Estimating Aluminium. Stock (*C. Rend.*, CXXX., Jan. 22d). A mixture of KI and KIO_3 reacts with an Al salt in this manner: $Al_2(SO_4)_3 + 5KI + KIO_3 + 3H_2O = Al_2(OH)_6 + 3K_2SO_4 + 6I$. The reaction progresses very slowly in the cold, but rapidly at the boiling temperature. The I generated can be removed as fast as formed by addition of standard $Na_2S_2O_3$. The precipitation is complete even in very dilute solutions.

Solution of *ignited Ferric oxide.* Bornträger (*Zts. Anal. Chem.*, XXXVIII., 774). On treating with HCl, and at the same time adding some (iron free) MnO_2, solution is easily effected, apparently by the aid of the Cl set free.

Chromium in Steel. Mahon (*J. Am. Chem. Soc.*, XXI., 1057). Dissolve 3 gms. of the sample in 50 c.c. conc. HCl. Boil down to a moist cake in a (covered) beaker. Then add 50 c.c. conc. HNO_3 and boil until the copious evolution of nitrous fumes have mostly ceased. Remove the heat when somewhat cooled, add 4 gms. $KClO_3$ and boil down (to 25 to 30 c.c.). Dilute to 300 c.c., add 15 c.c. of ammonia (Sp. Gr. 0.90). Stir well, filter and wash thoroughly with cold water. Dilute filtrate and washings to about 450 c.c. and titrate with standard solutions of $Fe(NH_4)_2(SO_4)_2$ and $K_2Mn_2O_8$.

Volumetric for Zinc. Pouget (*C. Rend.*, CXXIX., 45). The metal is precipitated by H_2S, in a solution containing $NaC_2H_3O_2$. After boiling out the excess of H_2S, the S combined with the Zn, and consequently the Zn is estimated by adding a known amount of standard I solution, and the excess of I titrated back by standard $Na_2S_2O_3$.

Zinc in Dried Apples, etc. Lehmann (*Zts. Anal. Chem.*, XXXVIII., 723). Destroy organic matter by moistening with HNO_3 and incinerating, or by fusion with Na_2CO_3 and KNO_3. Dissolve in HNO_3, separate Cu, etc., by H_2S, and Fe, Al, etc., by repeated precipitation with ammonia. In the combined filtrates separate Zn by H_2S in a solution slightly acid with $HC_2H_3O_2$, dissolve ZnS in a little HCl, and titrate with standard K_4FeCy_6.

Cobalt in presence of Iron. Bettin, R. (*Chem. Centr.*, 1899, 904). In a solution containing Co, addition of KCyS, and then pouring on a little ether-alcohol gives a blue supernatant layer. In presence of ferric compounds, the layer may be colored by the ferric compounds and the reaction thus masked. By addition of powdered $Na_2S_2O_3$ to the aqueous solution until the red color of $Fe_2(CyS)_6$ is destroyed, the addition of ether-alcohol will show the blue if Co is present.

Precipitation of Nickel by ammonia. Marshall (*Analyst*, XXIV., 202). Much basic Ni salt deposits, especially on warming, unless large amounts of NH_3 or ammonia salts are present. The presence of tartaric acid prevents this phenomenon.

Volumetric for Nickel. Giorgis (*Gazetta*, XXIX., 72). The Gibbs method—precipitation with alcoholic solutions of $H_2C_2O_4$ and titrating excess of $H_2C_2O_4$ in the filtrate, or else titrating the amount in the precipitate (in both cases by use of standard $K_2Mn_2O_8$) is defective in that $Ni_2C_2O_4$ is somewhat soluble, also that the alcohol cannot be entirely removed without destroying some of the $H_2C_2O_4$. These difficulties are avoided by using an $H_2C_2O_4$ solution of BaC_2O_4 or SrC_2O_4 (with known content of C_2O_4) and boiling. The use of alcohol is thus avoided, NiC_2O_4 being precipitated quantitatively. In other respects the operation is conducted as in the Gibbs method.

Nickel in its ores. Langmuir (*J. Am. Chem. Soc.*, XXII., 102). The important feature in the method described consists in the separation of iron as Fe_2Cl_6 by use of ether in presence of HCl. It is unnecessary here to quote fully all the details given. After decomposing the ore (1 gm.) with 15 c.c. HNO_3 and 1 or 2 c.c. liquid Br, converting to chlorides and separating Cu, etc., by H_2S, the Fe is oxidized by cautious addition of HNO_3, and the $Fe_2(OH)_6$ (carrying some Ni) precipitated by ammonia. The filtrate is boiled down while the precipitate is dissolved in HCl, and this solution boiled down to pasty consistency. This is rinsed into a separating funnel by use of HCl (Gr. 110) and about 40 c.c. of ether added. After agitation for about 5 minutes essentially all the Fe_2Cl_6 has been taken up by the ether. The aqueous solution is drawn off into a second funnel, and treated with a fresh lot of ether. The ether extractions are washed by agitation with a little HCl. The aqueous solutions containing the Ni are treated with ammonia after boiling off the ether, NH_4Cl expelled by boiling down with HNO_3, the bases converted to sulphates by evaporation with excess of H_2SO_4, excess of ammonia added and the Ni electrolyzed out (1.2 ampères).

Delicate Test for Stannous Chloride. Longstaff (*Ch. News*, LXXX., 282). The use of $SnCl_2$ as a test for MoO_3 is mentioned by Fresenius, but using MoO_3 solution as a test for $SnCl_2$ does not appear to be recorded. The author finds that the test is exceedingly delicate, one part in one and a half million of water being easily recognizable. The solution of Sn should not contain a large excess of strong HCl. The ordinary laboratory "molybdate solution" may be used. If $SnCl_2$ is present, a perceptible blue tint is obtained.

Separation of Arsenic, Antimony and Tin. Marburg (*Zts. Anal. Chem.*, XXXIX., 47). Treating the mixed sulphides with lime water and heating to 80° C. will readily dissolve As_2S_3 and Sb_2S_3 whereas Sn passes into combination with Ca which remains insoluble. The reaction serves perfectly for separation of Sb from Sn, but if the As present is more than 5 to 6 per cent. of the Sn, it does not completely separate those elements. A more elaborate treatment (which is described) must then be given.

Arsenic in Paris Green. Smith (*J. Am. Chem. Soc.*, XXI., 769). 2 gms. of the green are boiled for a few minutes with 100 c.c. of water

with addition of about 2 gms. NaOH. This separates CuO. The solution is cooled, made up to 250 c.c. and 50 c.c. filtered off (representing 0.4 gm.). This is boiled down to about 25 c.c. and then an equal volume of strong HCl, and about 3 gms. KI added. After standing 10 minutes the As will all be in the -ous form. Dilute—add $Na_2S_2O_3$ until the free I is just removed—neutralize with Na_2CO_3—then add $NaHCO_3$, and titrate with tenth normal I solution.

Parting of Gold-Platinum Alloy. Priwoznik (*Oester, B. & Hm. Ztg.*, XLVII.. 356). The method used in the Austrian assay office is as follows: Treat with HNO_3 (Sp. Gr. 1.199) to dissolve Ag. A little Pt will also be dissolved if Ag is present. Then treat with diluted aqua regia made as follows: 100 c.c. conc. HCl, 43 c.c. conc. HNO_3 and 143 c.c. H_2O. This dissolves Au with moderate ease, but does not materially affect the Pt. If Ag were not dissolved off by the first treatment some AgCl will form which will prevent solution of Au. Wash—dissolve off AgCl by ammonia, and treat again. Expel HNO_3 from the Au solution by evaporating with excess of HCl, and recover Pt by precipitation with NH_4Cl.

If the proportions of Au, Ag and Pt are nearly equal, fuse up with three times its weight of Zn. Dissolve out Ag and Zn by H_2SO_4 and treat the undissolved residue as described.

Separation of Gold from Platinum. Vanino and Seeman (*Ber.*, XXXII., 1968). Addition of NaOH or KOH followed by H_2O_2, causes reduction to Au in a few minutes in the cold. In the case of very dilute solution it is advisable to warm for a short time to destroy excess of H_2O_2. After this is accomplished to add HCl and filter. As Pt and Ir compounds are not reduced under these conditions, the process affords a method of separation.

Commercial Copper. Clark (*J. S. C. I.*, XIX., 27) Dissolve 10 gms. of the metal in HNO_3, evaporate to small bulk, render alkaline with Na_2CO_3 and redissolve the precipitate in HCl. Add to the cold solution 30 gms. KI, and then Na_2SO_3 solution until no free I is perceptible. Allow the Cu_2I_2 to settle, filter, and wash first with dilute HCl, then with water. From filtrate boil out SO_2, add $H_2C_4H_4O_6$ render alkaline with NaOH or $(NH_4)OH$, and add a little alkaline sulphide to separate remaining Cu and other metals except As, Sb and Sn. Boil, filter and acidify with HCl passing H_2S to insure complete precipitation of As. Let stand for some time before filtering. Rinse the still moist precipitate into a flask with 20 per cent. HCl, add twice its volume of HCl and distil off As as $AsCl_3$. Three distillations will suffice to remove all the As. Under these conditions the As recombines with H_2S in the receiver so that the point at which As ceases to come over may be approximately noted. The Sb and Sn in the flask may be separated by the $H_2C_2O_4$ method, but the author prefers to precipitate out Sb by addition of steel turnings and in the filtrate therefrom the Sn may be separated by H_2S, as SnS_2.

Silver Bullion by Volhard method. Rose (*J. L. Chem. Soc.*, LXXVII., 232). Conduct the process as in the Gay Lussac method (entire precipitate of Ag suspended in the solution) the accuracy is within 0.25 part Ag per 1000. If, however, the standard NH_4CNS solution is added in quantity sufficient to precipitate all but 0.0005 to 0.0010 gm. Ag and the so-

lution is then filtered, on adding $Fe_2(NO_3)_6$ or Fe alum with HNO_3, the titration may be finished with a limit of accuracy of 0.0001 gm. Ag. If an alloy contains *over* 50 of Cu per 1000 of Ag, the accuracy is not so great, but can be made so by checking up with test on a solution of pure Ag to which Cu has been added in approximately the same proportion as in the alloy under examination.

Silver in Plated copper articles. Girard (*Chem. Centr.*, '99, 27[5]). After thorough cleaning, immerse in a mixture of 9 volumes of H_2SO_4 to 1 volume HNO_3. This removes Ag completely without attacking the Cu appreciably. Separate and estimate Ag as chloride.

Brass analysis. Dederichs (*Chem. Centr.*, 1899, 950). Dissolve in the least possible amount of HNO_3, dilute with water containing 2 to 3 per cent. HCl and precipitate out Cu by H_2S. Estimate Zn in the filtrate.

For Cu digest the HNO_3 solution with $NaHSO_3$, add excess of standard NH_4CyS, filter, and in an aliquot portion of the filtrate titrate excess of NH_4CyS by standard $AgNO_3$.

"Weissmetal"—alloy of Lead, Tin and Antimony. Nessenson (*Chem. Ztg.*, XXIII., 868). Dissolve in dilute HNO_3, with $H_2C_4H_4O_6$. Add H_2SO_4 and heat to expel HNO_3, avoiding evaporating low enough to char the tartaric. Dilute with water and filter off $PbSO_4$, render alkaline with NaOH, add Na_2S to separate Cu—filter off and electrolyze at 80°C. with a current of 3 volts and 1.5 amp. This separates only Sb. Afterward add enough $(NH_4)_2SO_4$ to convert all Na_2S into $(NH_4)_2S$ and electrolyze, when Sn will be deposited.

Estimating Thallium as Chromate. Browning and Hutchins (*Am. J. Sci.*, VIII., 460). The solution is rendered alkaline with K_2CO_3, heated to 80° and then precipitated by excess of $K_2Cr_2O_7$. The precipitate should be collected on a Gooch asbestos filter washed, dried over a low flame and weighed. Precipitated in the cold, the Tl_2CrO_4 tends to run through the filter. This propensity is checked by NH_4NO_3.

Analyses of Tungsten Compounds. Ibbotson and Brearley (*Chem. News*, LXXX., 293). Adding strong HNO_3 drop by drop to a boiling solution containing $PbWO_4$, at a certain point there is a decided change of color in the precipitate from white to yellow, adding a few more c.c. of acid and boiling affords WO_3, which when filtered off and weighed gives nearly theoretical results. As the filtrates contain WO_3 the apparent accuracy must be due to a compensation of errors. The reaction does not occur in presence of NH_4 salts.

Ignited $PbWO_4$ containing more or less free WO_3 (as precipitated from solutions weakly acid with $HC_2H_3O_2$) may be completely dissolved in warm conc. HCl, from which WO_3 may be precipitated by dilution with water. Hg, Ur, Fe, Sn and Si interfere with accurate results by this method. As to the last, it appears to form silico-tungstate, which cannot be completely precipitated by Pb salts. Also, the separation of SiO_2 from WO_3 by use of ammonia or its carbonate is impossible (even after ignition) some SiO_2 being always dissolved by the alkali.

To analyze metallic tungsten powders used in steel making (containing 90 per cent. or more of W) the most expeditious method (giving approximate but probably not absolutely accurate results) is as follows: Weigh

out 3 gms. of the powder in a platinum dish. Roast to WO_3 and weigh (= *A*).

Treat with HF and reweigh—WO_3 + Fe and Mn compounds—(= *B*). Loss is SiO_2.

Add water, and NaOH (about half the size of a walnut). Dilute to 200–300 c.c. and boil. Filter, reserving filtrate and washings (*a*). Ignite the residue—Fe and Mn compounds with a little WO_3 (= *C*).

Dissolve the residue in a small amount of HCl. Dilute largely, filter off, and weigh precipitated WO_3 thus recovered (= *D*).

Then $B - C + D$ = amount of WO_3 from the powder originally taken.

Ferro-tungstens are not always completely decarbonized by simple ignition. The carbon therein may, however, be readily determined by combustion with PbO_2 or Pb_3O_4.

Chloride in small amounts in KBr. Baubigny (*C. Rend.*, CXXVIII., 1326). Dissolve about 6 gms. of the KBr with 18 gms. crystallized $CuSO_4$ in 110 to 120 c.c. of water, and then add 2.5 gms. $K_2Mn_2O_8$. Draw a current of air over the surface of the solution meantime heating up gradually on the water bath. After about 10 minutes of the full heat of the water bath, all Br has been removed. Add 0.5 gms. $K_2Mn_2O_8$, and heat again to complete the reaction, avoiding reduction of the bulk below 50 to 55 c.c. Cl may be determined in the residual liquid by the usual methods.

Separation of Chloride from Iodide. Vanino and Hauser (*Ber.*, XXXII., 3615). In KOH solution formaldehyd, reduces AgCl readily to metallic Ag, with AgBr the reduction is only partial, while with AgI no reduction occurs.

In a solution containing only chlorides and iodides precipitate by means of $AgNO_3$, wash thoroughly by decantation, allowing little or none of the precipitate to get onto the filter, then treat the precipitate with 25 c.c. of a 30-per-cent. solution of KOH and 5 c.c. of a 40-per-cent. solution of formaldehyde, warm to 30 or 40°C. and allow to stand for about 30 minutes. Then wash by decantation as before through the same filter. Dissolve out the metallic Ag by hot dilute HNO_3, and filter off AgI. The Ag formerly in the precipitate and now in solution in the HNO_3 may be precipitated by HCl, and the weight of the original Cl thus determined.

Iodic acid in commercial nitrate of Soda. Auzenat (*Mon. Sci.*, XIV. [4], Feb.). The process depends on the fact that acidification of solution of a mixture of iodate and iodide affords free I. In presence of the nitrate or perchlorate the stronger mineral acids will liberate I from iodide, but $HC_2H_3O_2$ does not cause interference of the kind. The author uses a set of six Nessler tubes or graduated test tubes. In the first is placed 10 c.c. of a solution containing 1 gm. KIO_3 per liter. A solution of the nitrate to be tested is made up containing 33 gms. per liter. In the comparison tubes respectively is put 30, 35, 40, 45 and 50 c.c. of this solution. Water is added to bring the volumes up to 50 c.c. in every case. Then 2 c.c. of a 10-per-cent. solution of KI is added to each, followed by addition of five drops of glacial acetic. Mix and let stand ten minutes before comparing the tints.

If none of the dilutions of the sample give a tint corresponding to the

standard, empty all out, and make a fresh comparison, using weaker or stronger solutions as the case may require. The addition of KI and $HC_2H_3O_2$ should be made as nearly as possible simultaneously, since the tint of the dissolved I alters by standing.

Chlorates, Bromates and Iodates. Vitali (*Boll. Chem. Farm.*, XXXVIII., 201). $MnSO_4$ with H_2SO_4 and KIO_3 gives a violet red solution. The coloration is not due to formation of $K_2Mn_2O_8$. Chlorates or iodates do not give this reaction. On boiling, Mn is precipitated as hydrated MnO_2.

Salts of hydroxylamine (but not the free base) liberate I in the cold from iodates. Heating will reduce bromates, but chlorates are unaffected. Salts of phenylhydrazine act in the same manner. In case of the presence of all three, cautious addition of $AgNO_3$ will precipitate only $AgBrO_3$ and $AgIO_3$. On suspending the precipitate in water, and passing H_2S, the Ag may be removed. In the filtrate acidified by H_2SO_4, I may be separated by adding a nitrite and shaking with chloroform. In the aqueous solution separate Br by Cl water.

Volumetric for Sulphur in Irons. Thill (*Zts. Anal. Chem.*, XXXVIII., 342). The H_2S evolved by boiling with HCl is cooled and passed into standard solution of As_2O_3. After filtering, the amount of As remaining is titrated with standard I solution (N/50).

Sulphur in Pig Iron. Moore (*J. Am. Chem. Soc.*, XXI., 972). The method of taking the samples for analysis was found to have a material influence on the results. The volumetric method gave uniformly lower results than the gravimetric method, and the error was decidedly greater in the case of "shot" samples (pouring the molten metal into water) as compared with "sand" samples (casting a small bar in a sand mould).

Sulphur in Coal. Antony and Lucchesi (*Gazetta*, XXIX., 181). Mix 1 part pulverized coal with 4 parts MnO_2, 1 part $K_2Mn_2O_8$ and 2 parts Na_2CO_3 in a platinum crucible. Cover with a layer of the oxidizing mixture, and heat up gradually to dull redness for half an hour, cool, treat with 40 to 50 c.c. of water, acidify with HNO_3 and boil. Filter and in the filtrate estimate SO_3 by $BaCl_2$. The method gives results identical with Eschkas method, and takes less time. A blank test with the oxidizing mixture is necessary, as MnO_2 sometimes contains sulphate.

Sulphur in Pyrites and in ores containing Iron. Heidenreich (*Zts. Anorg. Chem.*, XX., 233) and Meineke (*Zts. Anal. Chem.*, XXXVIII., 209). To obviate the well-known interference of Fe_2Cl_6, the Fe is reduced to the ferrous state by addition of Zn filings. The liquid is then filtered, and precipitated by $BaCl_2$.

Sulphydric, Sulphurous and Hypo-sulphurous Compounds. Feld (*Chem. Ind.*, XXI., 372). 1. *H_2S alone.* Boil with a concentrated solution of $MgCl_2$ in an atmosphere of CO_2—driving the gas over into solution of I which is afterward titrated. $H_2S + 2I = 2HI + S$.

2. *SO_2 alone.* Treat as for H_2S using HCl instead of $MgCl_2$ solution.

3. *$R_2S_2O_3$ alone.* Transform to $R_2S_4O_6$ by titration with I. Dilute and add Al foil and *dilute* HCl allowing the reaction to go on in the cold. The reaction occurring will be: $Na_2S_4O_6 + 20HCl + 6Al = 2NaCl + 3Al_2Cl_6 + 6H_2O + 4H_2S$. The H_2S may be boiled out and estimated as before, and "hypo" calculated.

4. *$R_2S_2O_3$ in presence of R_2SO_3.* The same method as in the preceding paragraph. The I oxidizes RSO_3 to RSO_4, not giving H_2S with the Al.

5. *R_2SO_3 in presence of $R_2S_2O_3$.* Add $HgCl_2$ in excess. The reaction will be: $Na_2S_2O_3 + HgCl_2 + H_2O = Na_2SO_4 + HgS + 2HCl$. To the solution apply method 2, the RSO_3 remaining unaltered.

6. *R_2S, R_2SO_3 and $R_2S_2O_3$.* First treat as in method 1, to get H_2S. Then treat with excess of $HgCl_2$ in the cold, as in 5, and distil with dilute HCl. This gives RSO_3. Titrate a fresh portion with I which converts R_2S to S and R_2SO_3 to R_2SO_4. Reduce by H_2S by Al as in 3, and determine $R_2S_2O_3$ as there described. No satisfactory method has been devised for admixtures of polysulphides, etc.

Silicon in Ferro-Chromium or Silica in Chromite. Tate (*Ch. News*, LXXX., 235). Fusion with five parts of Na_2O_2 is followed by solution in water, partial neutralization with HCl (leaving the solution somewhat alkaline) and evaporation to dryness. Then, on adding 40 c.c. conc. H_2SO_4 and heating, chlorochromic fumes (CrO_2Cl_2) are evolved, thus removing the Cr, which tends to cling persistently to the SiO_2. Heating is continued until white fumes of SO_3 are evolved, after which the solution is cooled diluted and the SiO_2 filtered off for weighing.

Graphitic Carbon in Irons. Ford and Bregows Ry. (*J. Am. Chem. Soc.*, XXI., 1113). One gm. of the sample is dissolved in HNO_3 (of Sp. Gr. 1, 12) better, without boiling. When solution is complete or nearly so a few drops of HF are added, more or less, according to the amount of Si present, and the solution boiled a short time. Dilute with 4 or 5 volumes of water, and filter through a weighted (platinum) Gooch with asbestos bed, dry and weigh. Ignite off graphite and weigh again, determining then by loss.

Kjeldahl Process for Nitrogen. Atterberg (*Chem. Ztg.*, XXII., 505). The solution most rapid in producing the desired decomposition is 20 c.c. conc. H_2SO_4, and 15 to 20 gms. K_2SO_4, together with a little Hg. In many cases it is more advantageous to add the K_2SO_4 when solution is complete. It was found that use of MoO_3 instead of Hg was of advantage as compared with various other oxides tried, but was not equal to Hg in hastening the operation.

Nitrogen in Fertilizers containing Nitrates. Veitch (*J. Am. Chem. Sc.*, XXI., 1094). A modification of the Gunning method has been described by Felds (Bulletin No. 46, U. S. Dept. Agric.) in which K_2S is used instead of K_2SO_4 and $Na_2S_2O_3$. The author uses another modification with good success, as shown by the results quoted. To the fertilizer in the digestion flask is added 35 to 40 c.c. H_2SO_4 containing 34 gms. salicylic acid per liter. Allow to stand in the cold until the nitrate is dissolved. Add 6 or 7 gms. finely broken K_2S, heat over a low flame for 15 minutes then over a full flame until clear. Cool and distil as usual.

Nitric Acid in Water. Russwurm (*Chem. Centr.*, 1899, 2, 593). The cresol reaction of Schneider is used (similar to Grandval Lajoux process). Of the preparation sold as *Kresolen pur. Nordl*, 20 c.c. of the portion distilling over at about 187° C. is mixed with 280 gms. conc. H_2SO_4 for the reagent. Five c.c. of this reagent are mixed with 2 c.c.

of the water to be examined. After 5 minutes 5 c.c. of distilled water are added, and after cooling 35 c.c. of ammonia and the solution made up to 50 c.c. (or 100 c.c.). The yellow coloration is proportional to the amount of HNO_3 present. It may be compared with that obtained by similar treatment of distilled water containing known amounts of HNO_3.

Coal Analysis. Report of committee (*J. Am. Chem. Soc.*, XXI., 1116). Directions for sampling are too long to be here quoted, except the remark that the operations should be conducted as rapidly as possible to guard against loss of moisture. Unless the coal contains under 2 per cent. of moisture, the shipment of large samples in wooden boxes is to be avoided. In any case shipment in sealed glass jars is preferable.

Moisture. Dry 1 gm. in an open crucible at 104° to 107° for one hour, best in a double-walled bath containing toluene. Where accuracy is required determinations should be made both on the coarsely ground and on the powdered coal. The first, on account of less exposure to drying out, is the more correct, and a correction must be calculated for all other determinations in which the powdered coal is taken.

Volatile Combustible. 1 gm. of fresh undried powdered coal is placed in a platinum crucible (20 to 30 gms.) with a tightly fitting cover. Heat for 7 minutes 6 to 8 cm. above a Bunsen burner, having a flame 20 cm. long when burning free. Application of the blast is not recommended. Applying the first heat slowly causes lower results for "volatile combustible." The top of the cover should burn clear, but the under side should remain covered with carbon.

Ash. The portion used for moisture can more readily be burned to ash than that used for expulsion of volatile combustible.

Sulphur. Eschka's method is recommended for general use. The use of an alcohol lamp for heating the dish containing the coal mixed with MgO and Na_2CO_3 is insisted upon. The presence of S in illuminating gas prevents its use when accuracy is required. It is advised that the residue of MgO, etc., insoluble in water, should be dissolved in HCl, and tested for the presence of additional sulphate.

CURRENT MINING CASES.*

OUSTER—MINING CLAIMS—PURCHASE-PRICE FUND.

Where one unlawfully ousts the owner from mining claims, and in working the same creates debts, such debts are not legal claims for liens against the mining claims. Idaho Gold Min. Co., *vs.* Winchell *et al.*, 59 Pac. Rep. (Idaho), 533.

MINING PARTNERSHIP.

Where tenants in common or joint tenants of an oil lease or mine unite and coöperate in working it, they constitute a mining partnership.

When members of a mining partnership cannot agree in management, those having a majority interest control its management in all things necessary and proper for its operation.

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A sale of his interest by a member of a mining partnership to another member or a stranger does not dissolve the partnership, as in ordinary partnerships. Childers *et al. vs.* Neely, 34 S. E. Rep. (W. Va.), 828.

MINES AND MINERALS—ADVERSE POSSESSION—PLACER GROUND.

Code Civ. Proc., 1895, § 494 (Comp. St., 1887, div. 1, § 40), providing that no action for the recovery of mining claims, lode claims excepted, or for the recovery of possession thereof, shall be maintained, unless it appears that the plaintiff or his assigns was seized or possessed of such mining claims within one year before the commencement of such action, is not applicable to real estate patented as placer ground, and hence adverse possession of such land for one year after the issuance of the patent is not sufficient to devest the owner of title. Horst *vs.* Shea *et al.*, 59 Pac. Rep. (Mont.), 364.

MINERAL LANDS—MORTGAGE.

When a mining corporation, in good faith, works, by ordinary mining processes, deposits of stone and other mineral on its lands, with a view to utilizing the product for commercial purposes, the land so worked is "mining ground," within the act of April 23, 1880, p. 131, § 1, making it unlawful for such corporations to sell, lease, or mortgage any part of their "mining ground, * * * unless * * * ratified by the holders of at least two-thirds of the capital stock," whether the undertaking is profitable or not, and whether sound discretion would approve that use of the land or not. Johnson *vs.* California Lustral Co., 59 Pac. Rep. (Cal.), 595.

MECHANICS' LIENS—WORK DONE FOR LESSEE.

A complaint in an action to enforce a mechanic's lien on a mining claim, showing that the plaintiffs were employed by and rendered services for the lessees of the owner of property, states no cause or action against the owner.

An owner of a mining claim, against whom a judgment has been rendered by default in an action to enforce a mechanic's lien for work done for her lessee, where there is an assignment of error which challenges the regularity of the judgment, is entitled to be heard on appeal, regardless of errors in her proceedings to open the default. Schweizer *vs.* Mansfield *et al.*, 59 Pac. Rep. (Colo.), 843.

MINING CLAIM—LOCATION—VALIDITY—POSSESSION—PUBLIC MINERAL LANDS.

Where, at the time of the location of certain mining claims, notices were posted thereon, and subsequently recorded in the record of the mining district, and the claims were marked by monuments, so that the boundaries could be readily ascertained, the location was valid.

Where plaintiff had held, occupied, and had been in possession of mining claims under color of title, in pursuance of law and the local rules and regulations of the mining district, for more than 20 years prior to the attempted location of the defendants, such claims were not public mineral lands of the United States, and plaintiff could maintain a suit to enjoin defendants' location, though there was no evidence of the transfer of the original locator's title to plaintiff. Risch *vs.* Wiseman *et al.*, 59 Pac. Rep. (Ore.), 1111.

MECHANIC'S LIEN—MINERS' WAGES.

An abstract on appeal in an action to foreclose miners' liens filed to secure the payment of some 30 miners' claims, each being a duplicate of the others, save as to names and amounts stating two causes of action, submitted under a stipulation of the parties, was sufficient, where it contained facts which enabled the court to decide the contested questions, and stated that all the other cases were precisely similar, except the names of the parties and the amounts.

A complaint by miners to enforce a miner's lien against the owner of the mine, alleging that they had been employed by its sublessee in accordance with the provisions of the original lease, and that their wages had not been paid, but failing to show that the owner of the land was privy to the contract of employment, or in any manner obligated for the payment of their wages, was insufficient. Little Valeria Gold Min. & Mill. Co. *vs.* Ingersoll, 59 Pac. Rep. (Colo.), 970.

COAL LANDS—LEASE—ROYALTY—ENTRY COAL.

A partnership agreement between N. and F. for mining coal on lands of N., and a lease of coal lands made at the same time to the firm by N., providing (the former) that the firm shall pay N., as royalty on said coal, 40 cents "for each and every 100 bushels of coal so mined, to be ascertained from the pay roll of said firm," and (the latter) that there shall be paid N. 40 cents "for each and every 100 bushels of coal mined and taken from said lands, as made up and taken from the pay rolls at said works," require payment of royalty on "entry coal," which is coal taken out in the construction in the mine of entries or passageways, though the cost of constructing entries is double the value of the coal gotten out of them, and though the practice of N. before the partnership, and thereafter of the firm, was to pay by the bushel for mining coal from the rooms, and by the yard for making entries; the number of bushels taken from the entries being deductible from the pay rolls showing the number of yards paid for to the miners. Jack *vs.* Forsyth, 45 At. Rep. (Pa.), 50.

MINING LOCATION: PROTEST AND ADVERSE SUIT, ANTEDATING NOTICE OF LOCATION.

In an action to determine ownership and right to possession of certain mining ground, evidence of statements, of one of several plaintiffs, as to the antedating by him of the location notice, made in the absence of his co-plaintiffs, and not concurred in by them, is hearsay, and inadmissible to bind them.

Fraud, when relied upon as a defense, must be specially pleaded in an answer as well as in a complaint; and, where fraud in making a mining location is not charged in the answer, evidence of admissions and declarations of the locator in relation to such location, tending to show fraud on his part, is inadmissible.

Where a locator of a mining claim on government land fraudulently antedates his notice of location for the purpose of defeating an actual locator thereon, such location is fraudulent as against such rightful claimant, and is also fraudulent as against the government.

The date of the location required to be given in the notice means the correct date, and not a fictitious or fraudulent date. Muldoon *et al. vs.* Brown *et al.*, 59 Pac. Rep. (Utah), 720.

MINING PARTNERSHIP—AGENCY.

Where plaintiff alleged a mining partnership with a wife, based on an agreement with her husband as her agent, evidence of statement by the husband that he was his wife's agent was inadmissible.

In an action for dissolution of an alleged mining partnership, plaintiff having shown that he purchased a one-half interest therein from the former owner, through a husband, who caused the other one-half to be deeded to his wife, and that plaintiff and the husband, who claimed to act as agent for his wife, worked on the mine, extracting mineral, and that the wife had made statements to third parties that she owned an interest in the mine and that her husband was her agent, it was error to nonsuit plaintiff on the grounds that he had shown no partnership, since the jury might have found that a partnership existed, within the meaning of Civ. Code, §§ 2511, 2512, provided that a mining partnership exists when persons own a mine for the purpose of working it, and actually do work the mine, though no express agreement of partnership exists. Ferris *vs.* Baker *et al.*, 59 Pac. Rep. (Cal.), 937.

MINERS' LABOR LIEN—MINE LEASES—LIABILITY OF LESSORS.

Where miners had filed liens for wages as authorized by Code, § 2940, an assignee of such claims was entitled to enforce the lien, and recover the penalty and attorney's fees authorized by such section.

Code, § 3105, declares that miners shall have a lien on all property of the person owning or operating a mine, and used in its construction and operation, including both real and personal property, for the full value of their labor. An owner of coal land leased the same, with the provision that the lessee should pay a royalty on coal mined, and that new machinery and improvements which the lessee might add to the mine should not be removed until after the lessor should have had a reasonable time to exercise his option to purchase the same. *Held* that, though the improvements equalled the value of miners' liens unpaid, the lienors were entitled to enforce their liens against both the mine and the improvements therein, though the owner had failed to collect royalties amounting to nearly the entire value of the improvements.

Code, § 3105, giving a lien against owners and operators of coal mines for labor performed in opening and operating the same, together with a penalty and attorney's fees for enforcement of such a lien, enters into and becomes part of a contract whereby one leases land to another for the purpose of being worked as a coal mine. Mitchell *vs.* Burdell *et al.*, 81 N. W. Rep. (Ia.), 193.

ADVERSE CLAIM—INTERVENTION—RECEIVER'S RECEIPT—FRAUD.

Rev. St. U. S., § 2326, and Act Cong. March 3, 1881, and amendatory thereof, allow 60 days from the filing of an application for a patent to a mining claim for the filing of adverse claims, and require suits to establish such adverse claims to be brought within 30 days thereafter. Code Civ. Proc., 1895, § 1322, provides that it is sufficient to confer jurisdiction upon the court, in an action to establish an adverse claim for a patent to a mining location, if it appears from the pleadings that the application for the patent had been made, and the adverse claim filed and allowed in the proper land office. *Held*, that one who has not filed

his adverse claim under the statute cannot intervene in an action to determine adverse claims to a location, though he claims an interest in the premises adverse to both plaintiff and defendant.

An entryman of a mining claim, who makes final entry thereof, and obtains the receiver's receipt therefor, showing he is entitled to a patent, is not relieved of the necessity of doing the annual representation work where such receipt was obtained by fraud.

Where a receiver's receipt, showing that the entryman of a mining claim is entitled to the patent, is subsequently annulled for fraud practiced in obtaining it, and the entryman has failed to do the annual representation work, the claim is subject to relocation.

Where a receiver's receipt, under which plaintiff is seeking to establish an adverse claim to a mining location, is shown to have been canceled, evidence of defendant's adverse location and publication of notice are admissible in evidence. Murray *et al. vs.* Polglase *et al.*, 59 Pac. Rep. (Mont.), 439.

MINES—LEASES—CO-TENANTS—UNDIVIDED INTEREST—OUSTER—DAMAGES.

Plaintiff brought action as lessee of the owners on an undivided one-third interest in a mine, under an instrument which recited that it leased unto plaintiff a one-third interest in the mine for one year, "the provisions of this lease to be as follows: The party of the second part hereby agrees to work said mine in a workmanlike manner, and to pay to the party of the first part royalty from all ores taken out * * * from the mine by the party of the second part." *Held*, that the instrument was a lease granting an undivided interest in the mine for the term of one year, and was not a mere license.

Defendant, the owner of an undivided two-thirds interest in a mine, refused to permit plaintiff, who was his co-tenant's lessee, to enter into possession of the mine, or to permit him to work the mine at a different level from where defendant was working, and threatened to scatter plaintiff's brains if he entered the tunnel leading to the ore bodies then developed. *Held*, sufficient to support a finding of an ouster of plaintiff by defendant.

Where plaintiff was lessee of an undivided one-third interest in a mine under a lease from the owners of said interest, and the defendant, who was the owner of the remaining undivided two-thirds interests, refused to permit him to enter into possession and work the mine, or any part thereof, plaintiff was not confined to an action for an accounting of the profits received by defendant during the term of the lease, but could maintain an action against defendant for damages, based on the loss of profits that plaintiff would have made but for the ouster.

In an action against the owner of an undivided two-thirds interest in a mine for excluding a lessee of the other undivided one-third interest therefrom, where it was shown that plaintiff was a practical miner, and that there was reasonable probability that he would have mined sufficient ore during the term of the lease to have yielded him a profit of $14,000 had he been permitted to work the mine as he proposed and intended to do, a verdict for $2,287.50 was not excessive.—Paul *vs.* Cragnas, 59 Pac. Rep. (Nev.), 857.

CONFLICTING LOCATIONS—INTERSECTIONS—PATENT ON MINING CLAIM.

Under Rev. St. U. S. § 2322, which provides that the locators of all mining claims on any mineral vein, where no adverse claim exists on the 10th day of May, 1872, "shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes and ledges, throughout their entire depth, the top or apex of which lies inside of such surface lines, extended downward vertically although such veins, lodes or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side lines of such surface location"; and Id., § 2336, which provides that "where two or more veins intersect or cross each other, priority of title shall govern, and such prior location shall be entitled to all ore or mineral contained within the space of intersection; but the subsequent location shall have the right of way through the space of intersection for the purposes of the convenient working of the mine"—the "space of intersection," in determining the ownership of ore within such space, where the claims cross and intersect on the strike of the lodes, means the intersection of the claims, and not merely of the veins; hence plaintiff, who located the prior claim, is entitled to all that portion of defendant's vein within the side and end lines of its said claims extended vertically downward, and for damages for ore removed therefrom.

Under Rev. St. U. S., § 2322, which provides that the locators of all mining claims on any mineral vein, where no adverse claim exists on the 10th day of May, 1872, "shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes, and ledges throughout their entire depth, the top or apex of which lies inside of such surface lines, extended downward vertically although such veins, lodes or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side lines of such surface locations"; and Id., § 2323, which provides that, "where a tunnel is run for * * * the discovery of mines, the owners * * * shall have the right of possession of all veins or lodes within 3 000 feet from the face of such tunnel on the line thereof, not previously known to exist, discovered in such tunnel, to the same extent as if discovered from the surface, and locations on the line of such tunnel of veins or lodes not appearing on the surface, made by the parties after the commencement of the tunnel, and while the same is being prosecuted, * * * shall be invalid"—blind leads. discovered while projecting a discovery tunnel through a prior valid subsisting claim, cannot be claimed by the owners of such tunnel.

Mills' Ann. St., § 3141, which provides that tunnel claims located for the sole purpose of discovery shall have the right of way through lodes which may lie in their course, is not made operative, by Rev. St. U. S., § 2338, which provides "that, in the absence of necessary legislation by congress, the legislature of the state may provide rules for working mines involving easements, drainage and other necessary means for their complete development," to apply to a tunnel located for the purpose of discovery, since the former section refers to tunnels for discovery only, while the latter provides only for easements for the development of mines.

Mills' Ann. St., § 3141, which provides that a tunnel claim located for the sole purpose of discovery shall have the right of way through lodes

which may lie in its course, has been superseded by Rev. St. U. S., § 2321, which provides that, "where a tunnel is run for * * * the discovery of mines, the owners * * * shall have the right of possession of all veins or lodes within 3,000 feet from the face of such tunnel on the line thereof, not previously known to exist, discovered from the surface; and locations on the line of such tunnel of veins or lodes not appearing on the surface, made by other parties after the commencement of the tunnel, and while the same is being prosecuted with reasonable diligence, shall be invalid," under which the owners of a tunnel for discovery have no right of way through a previous, valid, subsisting claim.

When a patent upon a mining claim has been issued, it conclusively settles, as against collateral attack, that all steps necessary to constitute a valid location of such claim have been taken; hence evidence by the owners of a tunnel site, who had tunneled and discovered blind leads underneath a lode claim upon which receiver's receipt had issued prior to the location of the tunnel site, and the patent issued thereto after such location, that no ore in place had been discovered on such lode claim, as required by law, thereby rendering it invalid, and fixing the ownership of such leads in them, was properly excluded.

Defendant, under a tunnel-site location, had entered (underneath the surface) plaintiff's claim, which had been located prior to such tunnel, with a view of extending such tunnel through the same under a supposed right, which, under the law, it did not possess. *Held*, that the overruling of defendant's motion for leave to develop blind veins, discovered by it in such tunnel within the lines of plaintiff's claim extended vertically downward, for the purpose of establishing their character, was proper, since such act would constitute a trespass upon plaintiff's property. Calhoun Gold Min. Co. *vs.* Ajax Gold Min. Co., 59 Pac. Rep. (Colo.), 607.

ALUMNI AND UNIVERSITY NEWS.

THOMAS EGLESTON MINUTE.

At a meeting of the Board of Managers of The Alumni Association of the Schools of Science of Columbia University, held February 1, 1900, a committee was appointed consisting of Professor A. J. Moses, Professor H. M. Howe, and Dr. L. McI. Luquer, to prepare a suitable minute, on behalf of the Alumni Association, in reference to the recent death of Professor Thomas Egleston, LL.D., and it was further,

Resolved, That this memorial minute be entered on the records of the Association.

Resolved, That the minutes be published in the SCHOOL OF MINES QUARTERLY.

Resolved, That the Secretary of the Association be requested to transmit a copy of this memorial minute to the family of the late Professor Egleston.

The Alumni Association of the Schools of Science of Columbia University having learned with deep regret of the recent death of Professor Thomas Egleston, Ph.D., LL.D., for many years an honorary member

of the Association, desire to put on record their appreciation of his life-work and services rendered to the old "School of Mines."

For thirty-four years Dr. Egleston filled the chairs of Mineralogy and Metallurgy in the "School of Mines," and relinquished his duties only when failing health made such a step necessary. Bringing with him to his work the broadening advantages of foreign training he threw himself heart and soul into the difficult task of organizing and developing what has since become one of the most important schools for mining engineering in this country, and from which have grown the other great Schools of Applied Science at Columbia.

In addition to his busy life as a college professor Dr. Egleston found time for many and varied outside interests, professional, historical and philanthropic; and was also a member of many of the scientific associations and clubs, and a constant contributor to scientific literature. His devotion to work was remarkable and untiring, being pushed at times to the limit of physical endurance, and undoubtedly in the end shortening his life.

Honors came to him both from abroad and at home, the degrees of Ph.D. and LL.D. being conferred by Princeton and Trinity respectively; and the French government appointing him a "Chevalier" and later in 1895 an "Officier" in the Legion of Honor.

One of the objects nearest to his heart was the collection of minerals in the Department of Mineralogy, which he built up from very small beginnings and to which, some few years before his death, he left his personal collection of minerals. As a tribute to his memory and in recognition of his very material assistance in the development of the mineralogical collection it is henceforth, by resolution of the Trustees, to be known as the "Egleston Mineralogical Museum."

Dr. Egleston, as an instructor, maintained a very high standard in his classes, and inculcated habits of order, neatness and industry, which could not fail to leave their mark on the subsequent life and professional work of the students.

ALFRED J. MOSES,
HENRY M. HOWE,
LEA MCI. LUQUER.

BOOK REVIEWS.

The Ore Deposits of the United States and Canada. Third edition; rewritten and enlarged. By JAMES FURMAN KEMP, E.M., Professor of Geology in the School of Mines, Columbia University. New York, The Scientific Publishing Co. 481 pages. Illustrated. Price, $5.00.

Mining engineers, and all who are interested in the subject of ore deposits, will be glad to welcome a new edition of this useful work. The first edition, published in 1893, was followed two years later by a second edition, partly rewritten and to which a number of additions were made. Professor Kemp has now brought up the record nearly to the end of 1899, and it is safe to say that, of the recent developments in the various metalliferous mining districts of the country which would serve to illustrate modes of ore occurrence, few have escaped notice.

A number of references to the ore deposits of British North America were made in the earlier issues of the work, and as more matter relating to the provinces has been inserted in the present edition the change of title to include Canada is a proper one. Nevertheless, the bulk of the new material, maps and illustrations, presented in this edition relate to the United States. It may not be amiss to indicate here the plan of the work, which, it must be remembered, deals only with the metalliferous mineral deposits.

Part I., comprising chapters 1 to 6, presents general geological facts and principles; the formation of cavities and fissures; the useful minerals, as distinguished from those composing the gangue, with the sources from which they were derived; modes of filling of mineral veins; structural features of veins, and systems of classification of ore deposits. A number of classifications have been framed by various writers, some of them based wholly upon form, others partly on form and partly on origin, one or two only being founded upon the genesis of the deposits. The classification adopted by the author is based wholly upon origin, and presents substantial advantages in point of breadth and thoroughness. In it the form of the deposit is treated as of minor importance. A synopsis of the classifications which have been proposed by other writers is given in an appendix, with brief comments

Part II., containing sixteen chapters, deals successively with the iron minerals, including limonite, siderite, the hematites, magnetite and pyrites; copper; lead; lead associated with zinc; zinc alone or associated with metals other than lead; lead and silver; silver and gold; gold, and finally the less important metals, such as antimony, bismuth, chromium, manganese, mercury, nickel and cobalt, tin, etc.

Under the heads of the various metals themselves, deposits are referred to the localities in which they are found in quantities sufficient to make them of economic value, and are considered in geographical order so far as possible. The modes of occurrence are illustrated by examples. The subject is treated in a somewhat flexible manner, as indeed is made necessary by the numerous irregularities found in ore deposits. Some of the examples are stated as typical cases. Elsewhere, for general cases are substituted references to, or brief descriptions of, particular deposits, followed by examples exhibiting minor variations. Due prominence is given to exceptional occurrences, without overloading the text by a multitude of citations. Valuable features of the work are to be found in the mass of specific references which, as foot-notes, accompany the text throughout, the list of general references grouped on pages 74 to 79, and a good index of 18 pages.

The book now contains 480 pages, 136 cuts and reproductions of photographs and 24 maps, as against 302 pages and 67 illustrations, of the first edition. Larger type has been used and the somewhat better quality of paper lends more distinctness and finish to many of the cuts. The statement which the author makes in the preface, that considerable portions of the text have been re-written, is borne out by a detailed examination. Evidences of careful revision are to be found in many places. Even a hasty perusal will lead the possessor of a copy of one of the earlier editions to the conclusion that he ought to have the new one also. It may be added that many readers would have appreciated greatly an

outline, contained perhaps in the preface, of the most important alterations and amplifications comprised in the new edition.

Some of the additions to be noted in a comparison with the first edition are the following:

Part I. In Chapter 2 the subject of "Formation of Cavities" has been re-written with a completer discussion of the agency of hot percolating waters in dissolving rock constituents. In Chapters 3 and 6 additional information is given as to the derivation of vein fillings and segregations from igneous formations.

Part II. Chapter 1 has been somewhat enlarged, specially under spathic ores. A new map shows the distribution of iron ores in North America. Chapter 2, on the hematites, is much extended by notices of the recent developments on the Vermilion and Mesabi iron ranges of Minnesota. Some new matter and illustrations are given in Chapter 3 on the magnetites. The brief reference to the pyrites of Louisa Co., Va. (pp. 184–5), we think hardly does justice to the relative importance of these interesting deposits. Chapter 4 contains considerable new matter on the Ducktown copper-bearing pyrite and pyrrhotite deposits and to the copper ores of the Butte (Mont.) district. On pp. 198–9 is reproduced the valuable map of the Butte district by the U. S. Geol. Survey. The Lake Superior copper deposits, with the discussion of their origin, also receive more attention. In Chapter 5 is a fuller description, with a good map, of the lead district in southeastern Missouri, just now the seat of renewed activity. The descriptions of the lead and zinc deposits of Virginia and the zinc of New Jersey have been re-written and further illustrated. Portions of Chapter 8, lead and silver, have been also re-written.

Under silver and gold, Chapters 9 and 10, important additions are made relative to recent developments in the Cripple Creek and Telluride districts, Colo., the Black Hills, Dak., and the various Montana and Idaho silver and gold districts. The Mercur and Tintic (Utah) regions also receive more attention. In Chapter 12 a few additions are to be noted on the new Randsburg district, Kern Co., Cal. The paragraphs on the geology of the gold belt of the Sierras, and the veins of the "Mother Lode," have been re-written and considerably expanded in the light of recent studies of the U. S. Geol. Survey. Chapter 13 contains new matter on the gold deposits of the Southern States, and on the Rainy River district in and north of Minnesota. A number of pages of recent notes on the various Alaskan and British Columbian gold fields are also inserted in this chapter, and the paragraphs on the gold deposits of Nova Scotia have been re-written. Chapters 14 and 15, on the lesser metals, have been greatly expanded.

In closing, we cannot refrain from expressing a wish that the author had entered into more detail in some directions: for example, regarding the great copper mines of Butte and Lake Superior, and the older copper district near the northerly end of Keweenaw Point; also more under the head of the gold quartz mines of California. But, the work as a whole is remarkably well-balanced in the treatment of the various metals and districts, and is concise and clear in style. Professor Kemp's untiring research among the monographs, and the mass of technical literature treating of the subject of ore deposits, have been supplemented by his own careful field-work, which has extended to many parts of the country.

The result is a book of great value, which appeals to the practical man as well as to the student.

R. P.

Steam Engine Theory and Practice. By WILLIAM RIPPER, M.Inst.C.E., M.Inst.M.E., Professor of Engineering, University College, Sheffield. Longmans, Green & Co., London and New York, 1899. 8vo. 398 pp., 438 illustrations.

In his preface the author states that this work was prepared originally as notes for second-year students of engineering and that it deals. therefore, in as simple a form as is possible, with those branches of the subject which are of fundamental importance. In view of these limitations, Professor Ripper's book is noteworthy not only for the wide range of topics treated, but as well for the fact that, although all are handled with necessary brevity, the essential elements of so many are—through compact and logical expression and abundant graphic illustration—presented with clearness and force. This is true especially of the chapters which relate to the quality and behavior of steam, in which the frequent use of the temperature-entropy diagram in the solution of practical problems, is a marked and commendable feature. The thermodynamics of the steam engine is, for a work of its size and scope, treated with unusual fulness and clearness. This is true also of such comparatively difficult topics as the theory of crank-effort, the balancing of engines, the action of the governor, etc.

On the other hand, while the compound engine is dealt with at some length, the triple expansion form is barely referred to, and the marine engine, in the description of types, is restricted to a few pages. Again, radial gears are omitted wholly from the chapter on the slide-valve; the study of fly-wheels, feed-heaters, and engine-friction is somewhat scant; and the compound locomotive, an engine of growing importance, is dismissed in a few lines. The chapter on engine-details is purely descriptive and contains little information as to the strength and proportion of parts. In the attempt to cover, within the limits of a moderate volume, a subject of so wide a range, some branches must necessarily suffer from compact treatment. Professor Ripper's work will be welcomed as a valuable contribution to educational literature, since, in space and completeness, it gives precedence to the study of the more difficult problems which confront the student of the modern steam engine.

W. L. C.

A Manual of Practical Assaying. By H. VAN F. FURMAN, E.M. Wiley & Sons, New York.

This popular and useful manual of assaying has now reached its fifth edition. The new features of this edition are two appendices: F, on the mechanical assay of gold and silver ores; G, on the calculation of copper matte blast furnace charges. The remaining portion of the book does not vary materially from the preceding editions. A few errors still appear in the book, such as the formula for manganese ferrocyanide on page 210b and the formula for determining the specific gravity of substances lighter than water on page 294. These are undoubtedly details which have escaped correction and do not impair the great value of the work as a thorough and comprehensive manual of practical assaying.

E. H. M.

Qualitative Chemical Analysis. By ARTHUR H. ELLIOTT, Ph.D., and GEORGE A. FERGUSON, Ph.B. New York, 1899. 8vo. 155 pages.

The third edition of Elliott's Qualitative Analysis under the joint authorship of Professors Elliott and Ferguson is an improvement and enlargement of the former editions. Many of the errors of the original work have been corrected, and while some still remain the improvement in this respect is marked.

The scope of the work has been decidedly enlarged, the actual gain being about 25 per cent. This is devoted mainly to the larger number of acids radicals dealt with, and the alternative schemes presented.

The tabular statements of special tests for acid and basic radicals is a new and valuable feature.

Certain points, however, seem to have been passed over, especially in the third group, where the alternative scheme of adding ammonium chloride and hydroxide and filtering, thus making two divisions of the group and effecting a great saving of time, has been ignored. The separation of chromium and iron by boiling with bromine and potassium hydroxide is also omitted, and when fusions are mentioned, sodium carbonate instead of sodium-potassium carbonate is invariably used. The formulæ of the various solutions and precipitates are mentioned in almost every case, yet some rather important compounds have been left out, notably where a precipitate dissolves in excess. This seems to be a mistake.

Chapter XIV., dealing with interfering acids, is an admirably arranged addition. The descriptions are clear and sufficiently explicit to cover any case that may arise. From the complicated and puzzling nature of these combinations and the cloudy manner in which their solution is often described in text-books, the student usually turns away with a feeling of helplessness, but here the whole matter has been so simply described that one can easily appreciate his task and by following the rules laid down may overcome any ordinary difficulty.

The Manual undoubtedly retains its standard character as an elementary work on qualitative analysis, it is free from the confusing details of larger works, and for the most part mentions methods of approved value. Very little further improvement can be attained, unless it should be brought about by the use of methods of quantitative analysis.

H. T. V.

A Practical Course in Mechanical Drawing. By WILLIAM FOX, M.E., and CHARLES W. THOMAS, M.E., with numerous illustrations. New York, D. Van Nostrand Company, 23 Murray and 27 Warren Streets, 1899. Price, $1.25.

This book is well adapted for a student of mechanical drawing who is commencing the subject without an instructor. The method used in the introduction for illustrating the orthographic projections of an object is clear, comprehensive and well calculated to impress one who has no knowledge of descriptive geometry. The use of the instrument is clearly shown; while the method of giving problems in isometric or perspective to be drawn in orthographic projection prevents the exercise from being mere reproductions of the plate as given.

S. O. M.

Éléments de Paléobotanique. By R. ZEILLER. Carré & Naud, Rue Racine No. 3, Paris, 1900. 8vo, pp. 421, figs. 210.

The first impression produced by this volume is that it is pleasing both to the touch and to the sight. The size is convenient, the covers are flexible, the corners of the pages are rounded and the typography and illustrations are clear throughout, so that its general style is in harmony with the purposes for which it is intended, namely, a text-book of paleobotany.

In the arrangement of the subject two different points of view are recognized and the work is thus divided into two parts. In the first part fossil plants are discussed systematically, in accordance with our modern ideas of the biologic sequence of living plants, beginning with the lower and ending with the higher families. In the second part they are considered in their time sequence or in the order of their appearance in successive geologic periods.

There are introductory chapters, containing brief references to the beginnings of and the principal works on paleobotany, from the time of Scheuchzer's "Herbarium Diluvianum," in 1709, to Seward's "Fossil Plants," not yet completed; methods of preservation of fossil plants; their classification and nomenclature. The volume ends with a chapter in which critical points are discussed and a bibliography and index are appended.

The treatment of the subject is necessarily brief, but the sequence adopted is excellent and the illustrations are well chosen. Possibly a somewhat disproportionate amount of space and illustration is given to the Cryptophytes and Gymnosperms as compared with that given to the Angiosperms, but as the former undoubtedly present greater difficulties to the student this disproportion may well be excused.

The work is essentially a text-book and it will find an excellent sphere of usefulness amongst those who are beginners and those who are engaged in giving instruction in the science of which it treats. To such it will prove a very handy volume in which the entire field is covered in an elementary but thoroughly scientific manner.

A. H.

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CONTENTS:

The Question of Temperature-Influence on the Specific Rotation of Sucrose. By Ferdinand G. Wiechmann, Ph.D..... 299
The Course in Architectural Practice. By C. P. Warren, Ph.B..... 337
The Conflict Between Sir Isaac Newton and the French School of Astronomers Concerning the Figure of the Earth. By D. H. Pollard..... 350
On the Production of Asymmetrical Alternating Currents by Means of Electrolytic Polarization. By Walter Leo Hildburgh, E.E., A.M..... 358
Mean Effective Temperature a Unit of Comparison for Heat Engines. By Charles E. Lucke..... 382
The Assay Practice of the West Compared with that of the School of Mines. By Charles Fulton..... 394
Abstracts—Current Mining Cases..... 398
Book Reviews..... 407

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SCHOOL OF MINES QUARTERLY.

VOL. XXI. JULY, 1900. No. 4.

THE QUESTION OF TEMPERATURE-INFLUENCE ON THE SPECIFIC ROTATION OF SUCROSE.

BY FERDINAND G. WIECHMANN, PH.D.

Member, The International Commission for Uniform Methods of Sugar Analysis.

In studying the question of temperature influence on the polariscopic reading of a sucrose solution, it is important to pay due regard to the temperature at which the solution is prepared and to the temperature at which it is observed.

Two distinct cases call for consideration:

A. The sucrose solution is prepared at a given temperature but polarized at some other—higher or lower—temperature.

B. The sucrose solution is prepared at a given temperature and polarized at that same temperature.

In either case, if we assume the polarizations to be obtained by means of a quartz-wedge compensation saccharimeter the influence of temperature on the quartz-wedges of the instrument must be taken into account. If the readings on the saccharimeter be made at temperatures higher than the temperature at which the saccharimeter has been graduated, the readings obtained will be too low, if made at a temperature lower than the temperature at which the instrument has been graduated, the readings obtained will be too high.

Polarizations made on sucrose solutions prepared with the aid of clarifying reagents will—*eo ipse*—be too high on account of the

unavoidable concentration of the solution, caused by the presence of the precipitate, a solid which is formed in the solution.

Disregarding for the present both of these possible factors of error let attention be confined for the moment to the manner in which the sucrose solutions themselves can be influenced by temperature changes in the two instances under consideration.

In the first case, *A*, a sucrose solution which exactly and wholly fills the polarization tube at the temperature at which the solution has been prepared and introduced into the tube, must, on suffering a change of temperature, necessarily change its volume.

If the solution be cooled it contracts; if heated, it expands.

In the latter instance a part of the solution will force its way out of the tube; in consequence, there will be less optically active solution in the tube at the higher temperature and the polarization then observed, must, of necessity, be lower.

In the second case, *B*, any change of volume of the solution is avoided because the sucrose solution is polarized at the same temperature at which it has been prepared.

Concerning the result to be obtained under these circumstances there is a marked difference of opinion among investigators.

Some maintain that a solution of sucrose which gives a polarization of 100° Ventzke when prepared at 17.5° C. and polarized at 17.5° C., will also give a polarization of 100° Ventzke when prepared and polarized at respectively, 20° C., 25° C., 30° C., or at any other temperature, it being of course clearly understood, that proper correction is requisite for the influence of temperature on the quartz-wedges of the saccharimeter as well as for any precipitate-error, should such have been introduced through a clarification of the solution.

There are however some investigators who are opposed to the above contention. They claim that the higher the temperature at which sucrose solutions are respectively prepared and polarized the lower will be the polarizations obtained. In explanation of these alleged variations in the polarization-readings secured at different temperatures, they allege an influence of temperature on the specific rotatory power of sucrose.

The literature bearing on the question at issue may, for the sake of convenience, be divided into two groups, one, in which an influence of temperature on the specific rotatory power of sucrose is claimed, the other, in which such influence is denied.

Among the writers whose names have been assigned, in some instances without proper warrant, to the former of these divisions, there should be cited:

1846.	Dubrunfaut.	1893.	Gravier, E.
1889.	Andrews, C. W.	1895.	Harrison, J. B.
1889.	Petrucci and Sachs, F.	1896.	Sachs, F.
1889.	Wartze, B.	1897.	Schönrock, O.
		1898.	Wiley, H. W.

Among representatives of the second group, there may be named:

1842.	Mitscherlich, E.	1882.	Lippmann von, E. O.
1843.	Ventzke, K.	1890.	Seyffart, J.
1858.	Arndtsen, A.	1893.	Josse, A.
1860.	Berthelot, M.	1897.	Lippmann von, E. O.
1870.	Tuchschmid, C.	1898.	Seyffart, J.
1875.	Hesse, O.	1898.	Wiechmann, F. G.
1878.	Wachtel von, A. O.	1899.	Herzfeld, A.

To gain a thorough understanding of the question, to impartially regard the problem from the different points of view, the writer has deemed it necessary to study the pertinent publications of all of the authors named above. This he has done and herewith he respectfully presents for the consideration of the International Commission for Uniform Methods of Sugar Analysis his comments and criticisms on those writings.

Dubrunfaut, who is sometimes quoted as an early writer on this topic, is said to have maintained that temperature exerts an appreciable influence on the specific rotation of sucrose.

Reference to his article, entitled: "Note sur quelques phénomènes rotatoires et sur quelques propriétès des sucres" (Annales de chimie et de physique [3], Vol. 18. *1846*, pp. 99–107), shows him to state:

"Les dissolutions de sucre de canne, de sucre de fruit * * *, sont, parmi les substances que j'ai pu examiner jusqu'à présent celles qui subissent, dans leurs propriétés rotatoires, des changements qui varient avec la température" (pp. 100–101).

"Le sucre de canne n'éprouve qu'un abaissement de 0,04 dans son pouvoir rotatoire pris à 18, 7 de température en le chauf-

fant à 80 degrés. En corrigeant ce nombre à l'aide de coefficients de la dilatation du laiton (matière du tube) et du sirop, on trouve que le pouvoir rotatoire du sucre de canne, pour une transition de 100 degrés de température de 0 à 100 degrés, ne serait abaissé que de 0,0232 du pouvoir rotatoire pris à zéro; ce qui ne représente qu' une quantité très-petite par rapport à l'effet analogue que subit le sucre interverti" (pp. 101–102).

Dubrunfaut therefore evidently makes no statement beyond that of the fact he observed, that a solution of cane-sugar experiences a lowering of 0.04 of its rotatory power determined at 18.7° C., *when heated to 80 degrees.*

What other result than a lowering in polarization could possibly have followed such heating of a cane-sugar solution?

But in what manner can this experience of Dubrunfaut's be construed into a claim that Dubrunfaut had ascertained a depression of the specific rotatory power of sucrose due to an elevation of temperature? His method of procedure undoubtedly caused decomposition of some of his sucrose, and of necessity resulted in the finding of lower polarization-values after the heating of the solution.

Dubrunfaut can therefore not be cited as an advocate of the views held by those who allege an influence of temperature on the specific rotatory power of sucrose.

Andrews, whose name is next on the list given, published two articles in the *Technology Quarterly*, May, 1889.

They shall be separately considered. The first of these is entitled: The Influence of Temperature on the Specific Rotation of Cane Sugar (pp. 367–371).

This investigation is based on the examination of two, and only two, sugar solutions.

The first of these was observed in a Laurent large model polariscope at 18° C. and at 41° C.

The second solution was read at 19° C., then at 39.9° C. and finally at 20.1° C.

In speaking of the mean change in the specific rotation per degree Centigrade, as found in the two determinations referred to, Andrew says:

"The agreement * * * is so close that there should be no serious error in taking the mean of the two," etc.

Let us examine how close this agreement really is:

Value found by first determination	0.0106.
" " " second "	0.0122
Difference between the two determinations	0.0016

This difference amounts to 15.09 per cent. of the value first found and to 13.11 per cent. of the value found in the second determination—hardly a very close agreement considering the order of magnitude finally to be determined.

But, waiving this for the moment, let us examine the expression which Andrews obtains in "taking the mean of the two," to show the relation of the specific rotation to the temperature.

Andrews' formula is:

$$[\alpha]\frac{t}{D} = [\alpha]\frac{20}{D} - 0.000114\,(t-20).$$

This formula is wrong.

The corrected Andrews' formula, expressive of the influence of temperature on specific rotation, is the following:

$$[\alpha]\frac{t}{D} = [\alpha]\frac{20}{D} - 0.0114\,(t-20).$$

His results lead Andrews to find as "the coefficient of change per degree Centigrade," the value 0.000171 on the basis of 66.50 as the mean value for $[\alpha]\frac{20}{D}$.

In calculating his specific rotation value, Andrews, in averaging some of his determinations says (p. 370): "It is evident that the variations of the separate readings from these means are due in part to two causes which are compensated for in taking the mean, viz, the difference in the temperature and *a slight eccentricity of the graduated circle and the optical parts of the instrument.*" *

It certainly seems justifiable to say—in the face of these statements and in consideration of the very limited experimental data on which Andrews' work is based—that his conclusions do not carry home conviction to those who are capable of drawing their own inferences as to the character of his investigation and the value of the data which he has secured.

* Italics by F. G. W.

The second paper of Andrews is given in the *Technology Quarterly* (May, 1889), pp. 372–378.

In this article Andrews states that unquestionably the most accurate results in polarizing can be obtained by making up all the solutions and reading them at the temperature at which the saccharimeter was graduated.

But as this "is inconvenient for rapid work," he has calculated "the factors by which the observed reading should be multiplied to obtain the true reading." Concerning the question of special interest to us he then states: "The change in the specific rotation of the solution was found from the formula:

$$1 - 0.000171\ (t - 17.5).$$"

On p. 373, Andrews then gives four columns of factors adapted for use under various conditions. The only one of these of importance for our present purpose is the second column, which contains the factors for a solution made and read at t°, against quartz. These factors are calculated for the Ventzke standard solution in brass tubes.

The temperatures and the factors corresponding to the same are:

t	Factors
10	0.9978
15	0.9993
17.5	1.0000
20	1.0007
25	1.0022
30	1.0036
35	1.0051
40	1.0067
Mean change per degree from 17.5 to 40	0.00030.

Andrews states that these factors may also be used without error for other solutions and glass tubes; the difference between glass and brass tubes being 0.0002 at 40° C.

Attention shall now be directed to the closing paragraph on page 373 and the data there given. This paragraph shall be quoted *in extenso.*

"That the corrections here given are not too large will be seen from a comparison of the reading of a standard solution on several

different saccharimeters at different times. The solutions were prepared by weight and the readings are the means of a large number of observations. The first column gives the actual reading at the temperature given; the second, these readings corrected by Matecgzek's table for density alone; the third, the same corrected by the factors given above.

	t	1.	2.	3.
1 C. S. Color	23	99.77	99.92	100.10
2 C. S. Color	23.2	99.79	99.94	100.12
3 C. S. Color	25.4	99.67	98.88	100.13
4 C. S. Color	24.4	99.46	99.64	99.86
	27.9	99.39	99.68	100.00
5 S. & H. Color	28	99.23	99.52	99.85
6 S. & H. Shade	29	99.11	99.43	99.78
Mean			99.72	99.98
Greatest variation from 100			0.57	0.22"

We have here readings obtained in six different saccharimeters and representing two different makers; five of these instruments were color instruments, and one was a half-shade saccharimeter. As Andrews makes no mention whatsoever as to having tested the correctness of these instruments, and as he draws his mean from the readings obtained in them all, we must assume that they were all correct, or at least, that they were all equally correct.

Bearing this in mind and being informed by Andrews that the readings so recorded (in column 1), are the actual readings at the temperature given, obtained on "a standard solution," we must naturally wonder at the wide discrepancies exhibited by the figures recorded in column 1.

The temperatures comprised in these various observations vary from 23° C. to 29° C., that is to say, cover a range of only 7° Centigrade. The differences in polarization, exhibited under these conditions referred to the highest polarization recorded as a standard of comparison, amount to:

t	Differences:
23	—0.02
23.2	0.00
25.4	—0.12
24.4	—0.33
27.9	—0.40
28	—0.56
29	—0.68

In other words, for a difference of 6° Centigrade a difference in polarization of 0.68° Ventzke is recorded.

Nor is the difference per degree Centigrade within the range given at all uniform, as the following table shows:

Temperatures at which the readings were taken in the polariscopes.	Differences between the temperatures recorded.	Differences between the polariscope readings obtained in degrees Ventzke.	Difference in degrees Ventzke per degree Centigrade.
23.2 and 25.4	2.2	0.12	0.054
23.2 " 24.4	1.2	0.33	0.275
23.2 " 27.9	4.7	0.40	0.085
23.2 " 28.0	4.8	0.56	0.116
23.2 " 29.0	5.8	0.68	0.117

Here we have values—degrees Ventzke per degree Centigrade—which vary among themselves—to choose the extreme data secured—by more than 400 per cent.

And yet Andrews does not hesitate to combine them for the purpose of drawing "means" from them and for the purpose of employing them as the basis of an illustration of the need and the value of his "correction factors."

Regarding his column 3, it will be noticed that the difference between Andrews' "*corrected*" readings may amount to as much as 0.35° Ventzke. *Vide:*

100.13 and 99.78.

This difference corresponds to a difference of 3.6 degrees Centigrade. For this range Andrews' maximum correction factor is 0.108 (*i. e.*, 0.03 × 3.6). Therefore, the variation in Andrews' "corrected" readings is equivalent to *three times* the maximum correction which he advocates.

Glancing at columns 2 and 3 of this table of Andrews' it will be seen that the first three out of seven of his figures in column 2, "corrected for density alone" come closer to 100, which should be the true value of his "standard solution"—than the corresponding

values corrected also—by Andrews' factors—for the supposed influence of temperature. Compare column 3 with column 2.

	2 Diff.		3 Diff.
100.00	99.92 — 0.08	100.00	100.10 + 0.10
	99.94 — 0.06		100.12 + 0.12
	99 88 — 0.12		100.13 + 0.13
	99.64 — 0.36		99.86 — 0.14
	99.68 — 0.32		100.00 0.00
	99.52 — 0.48		99.85 — 0.15
	99.43 — 0.57		99.78 — 0.22

Only in one single instance is the value 100.00 obtained in his column 3 of "corrected" polarization values, while in three instances, were we to credit these figures, we would have to believe that "standard" sugar solutions can polarize *more than 100 per cent!*

Passing on to the work of Petrucci and Sachs, the writer regrets to state that their publication was not accessible to him. It is said to have appeared in the Bull. Assoc. Belge Chim., 15 Feb., 1889, p. 112.

However in speaking of the experiments of Petrucci, Sachs says (Zeitschrift des Vereins für Rübenzucker Industrie, *1896*, p. 267) that he, Sachs, could not find the differences in polarization as great as Petrucci claimed to have observed.

As Petrucci's observations were made on sugar solutions, the temperature of which was allowed to drop from 17°C. or 18°C. down to 2°C. or 3°C. before repolarization, his work is not in accord with the conditions which govern the polarization of solutions to be observed at the temperatures of their preparation.

Moreover, as Sachs himself has discredited, or, at least, has been unable to affirm the correctness of Petrucci's claims, the latter may be dismissed from our consideration without further scrutiny.

In 1889 B. Wartze published an article "Ueber Polarisations differenzen" (Die Deutsche Zuckerindustrie, *1889*, p. 503).

From his statements it appears that he made up his solution at the temperature at which his sugar flasks were graduated (*i. e.*, presumably at 15.0°C. or at 17.5°C.), and that he then polarized the solution.

The temperature of the solution was next obtained by inserting a thermometer into the polariscope tube; the loss of solution

caused by insertion of the thermometer was made good by the addition of some of the filtrate held in reserve and which had been guarded against evaporation.

The solution, thus anew enclosed in the polarization tube, was then either warmed or cooled.

The warmed solution was polarized and its temperature ascertained. In case of the cooled solutions the small air bubbles which had been caused by contraction of the fluid were displaced and replaced by the addition of a drop or two of the filtrate held in reserve and which was practically of the same temperature. The solution was then again polarized.

It is not surprising that under such methods of procedure, where on *warming* a part of the solution *escapes* by pressing through the rubber rings of the polariscope-tube, and where, *after cooling addition* of optically active solution is made to the original contents of the polariscope tube, that the readings at the *higher* temperatures should always be *lower* than the readings obtained at inferior temperatures. The differences which occur are marked; wide discrepancies are shown. See the following table which exhibits variations of:

0.9°	Ventzke	for a	difference	of	20° C.
1.4°	"	" "	"	"	24° C.
0.3°	"	" "	"	"	6° C.
1.5°	"	" "	"	"	28° C.
0.6°	"	" "	"	"	10° C.
0.6°	"	" "	"	"	11° C.

Moreover, all of Wartze's tests here considered, were obtained in a saccharimeter which stood in a heated room. Therefore, aside from all other objectionable features, Wartze's results also suffer from a non-correction for temperature-influence on the quartz-wedges of his instrument, and certainly no inference can be drawn from his work as to whether or no temperature exercises any influence on the specific rotatory power of sucrose.

The investigation of Gravier, "Influence de la température sur la polarisation des liquides sucrés," appeared in the Bull. de l'Assoc. des Chimistes de Sucrerie et de Distillerie, Vol. XI., 1893, p. 2–3.

His experiments were made with a Schmidt and Haensch saccharimeter and with use of the normal weight 26.048 grammes.

Gravier studied particularly the effects of expansion and contraction on the results of the polarizations obtained, and also demonstrated the error of Wartze's work in this respect, which has been referred to above.

Gravier's work was carried on with series of solutions made up respectively at 16° C. and at 32° C.

He found differences between the polarizations of these solutions, made up and polarized, as has been said, at 16° C. and at 32° C., and ascribed these differences to the influence of temperature on the rotatory power of the sugar-solutions, as in his experiments the influence of dilation and expansion of the solutions had been allowed for.

The error into which Gravier fell was that he did not allow for the influence of temperature on the quartz-wedges of his saccharimeter. He indeed had this source of error in mind, but unfortunately tried to learn whether the temperature affected his saccharimeter by observing the zero-point of the instrument at 23° C. and again observing this zero-point after the temperature of the instrument had been kept for a certain time at 45° C. As he correctly observed, no change whatever could be noticed in the adjustment of the zero-point. But as is now well known (see Landolt, Optisches Drehungsvermögen Organischer Substanzen, p. 344), "only the zero-point is independent of the temperature, all other points of the scale, however, change their value with the temperature."

Gravier's results would have been different had he selected any other part of the saccharimeter-scale for his observations.

Passing reference may here be made to a paper by J. B. Harrison, dealing with the polarization of sugar in tropical climates (Timehri: *The Journal of the Royal Agricultural and Commercial Society of British Guiana.* Demerara, December, 1895. Vol. IX. New Series. Part II., pp. 378–382).

The article contains no evidence whatever in support of the statement, made by its author, that: "The rotatory power of sucrose solutions decreases slightly by rise of temperature (irrespective of changes of volume), and this has the same effect upon the polariscope indications."

The difference between the "true sugar polarizations" which he claims for the samples tested and the experimental data which he cites, may have been caused by one or more of several possible

sources of error which, apparently, the author did not take into account at all.

In the first place, due allowance should be made for the influence of temperature on the saccharimeters used; the temperature of the instruments must have been about 28° C. throughout.

Having introduced the correction necessary to effect this (Jobin's correction), the remainder of the "residuary error" may have been caused by:

a. The presence of moisture—varying amounts in different experiments—in his sugar samples. In view of the very damp climate of the colony where Professor Harrison's work was done, this may very readily have been a disturbing factor.

b. The wedges or other quartz parts of some of his instruments may have suffered stress owing to the unequal rates of expansion of quartz and the metal in which the quartz was set; this, of course, would vitiate the scale indications. In this connection it should be borne in mind that the instruments used were all built and graduated in a climate much cooler than the one in which they were used by the experimentator.

c. The scales of some of the instruments may have been faultily graduated in the first place.

The author has made no attempt to show that the causes here mentioned did *not* affect the results he obtained.

Until this has been done he is certainly without warrant in *arbitrarily* ascribing the differences, which he has *simply not accounted for*, to the influence of temperature on the specific rotatory power of sucrose.

It has been Professor Harrison's practice while in the West Indies, "to standardize all the measuring instruments used to true cubic centimeters" (p. 379). His method of procedure, in getting around climatic difficulties in polarizing, is rather unique and deserves being quoted. He writes: "As the range of temperature here is not very great, I consider that the method used in the Government Laboratory for the last fourteen years is the best. Each 100-cubic-centimeter flask in use for sugar polarizations is verified by weighing into it 99.533 grams of recently boiled distilled water at 28° C. The exact weight of chemically pure sugar, which when made up to a bulk of 100 cubic centimeters in one of the corrected flasks at 28° C. gives a polarization reading of 100°, is ascertained by experiment for each instrument and this weight

of sugar is invariably used instead of the maker's normal weight for 17.5° C." (p. 382).

The next study of our problem to claim attention is the work of F. Sachs on the "Influence of Temperature on the Polarization of Sugar" (Zeitschrift des Vereins der Deutschen Zucker Industrie, 1896, pages 264–270).

The actual experimental work of this investigation is by Sachs credited to his assistant, P. Xhoneux.

Confining our attention solely to those of his experiments in which the sugar solutions were polarized at the same temperature at which they were prepared, we find the following:

	Series I.	Series II.	Mean.	Difference referred to value at 15° C.
Prepared at 15°C. Observed at 15°C.	95.30	95.30	95.30	0.0
Prepared at 20°C. Observed at 20°C.	95.25	95.20	95.22	—0.08
Prepared at 25°C. Observed at 25°C.	95.15	95.05	95.10	—0.20
Prepared at 30°C. Observed at 30°C.	95.00	94.90	94.95	—0.35

These observations were made on normal weight solutions.

Sachs adds:

"With more dilute solutions the influence of temperature would of course be even less."

Sachs has apparently neglected to introduce any correction for the influence of temperature elevation on the quartz-wedges of his saccharimeters.

It is true that, as far as we have been able to find, Sachs makes no specific mention of the temperature of his saccharimeter during his observations, but, presumably the saccharimeter of Sachs was also of the same respective temperature at which Sachs made up and polarized his solutions.

Assuming 15° C. to have been the temperature at which Sachs' polariscope was graduated, and using Jobin's formula, there must be *added* to the values found at 20° C., at 25° C., and at 30° C. respectively, the amounts:

0.076, 0.152, 0.228.

This brings the figures of Sachs to:

		Difference from Value Found at 15° C.	Difference in Degree Ventzke per Degree Centigrade.
At 15° C. =	95.300 =	0.000	
" 20° C. =	95.296 =	0.004	0.0008
" 25° C. =	95.252 =	0.048	0.0048
" 30° C. =	95.178 =	0.122	0.0081

These differences all fall well within the allowable limit of experimental error, and it is, therefore, probable that the differences found by Sachs are wholly accounted for by the change in optical value which the quartz-wedges normally experience by the elevation of temperature, leaving no appreciable margin for any "lowering" in the specific rotatory power of sucrose induced by an elevation of temperature.

The work of Sachs would therefore rather seem to confirm the results obtained by the investigators whose views are in opposition to his own.

Referring to the experiments made by von Wachtel—as cited by Sachs in his paper just discussed—von Wachtel observed differences of 0.3, 0.2, 0.2, 0.3, 0.3, 0.3, or, in the mean, a difference of 0.27° Ventzke for a range of 8 degrees Centigrade.

Of this amount, viz, 0.27° Ventzke, expansion of the fluid *is said to account* for only 0.11° Ventzke.

This, however, is wrong. As Landolt's work—Das Optische Drehungsvermögen Organischer Substanzen, 1898, states (p. 345), the change in polarization of a pure sugar solution *due to the change of volume, is 0.029° Ventzke for each degree of temperature.*

In the case of von Wachtel's figures we have, therefore, to allow for expansion—

$$0.029 \times 8 = 0.232° \text{ Ventzke},$$

or, in other words, his experiments show a difference of only

$$\begin{array}{r} 0.270 \\ -\,0.232 \\ \hline \end{array} = 0.038° \text{ Ventzke}$$

for 8 degrees Centigrade. This is equivalent to a difference of only 0.0045° Ventzke per degree Centigrade, a difference which may well be due to the cause suggested by von Wachtel himself, namely, expansion of the quartz-wedges of his polariscope.

Von Wachtel, therefore, is also in agreement with the investigators who deny that temperature exercises an influence on the specific rotatory power of sucrose. Sachs and Wiley have evidently been mistaken in seeking to adduce the work of von Wachtel in support of their contention.

Among the most important contributions to to the question under discussion there must be reckoned the writings of Dr. O. Schönrock, Berlin. His publications have appeared in Professor Landolt's book: *Das Optische Drehungsvermögen Organischer Substanzen*, consult especially pp. 344–346, "The influence of temperature on the readings of saccharimeters," and in the Zeitschrift für Instrumentenkunde, 1897, Vol. 17, pp. 178–181, where they appear in the report of the doings of the Physikalisch-Technische Reichsanstalt.

Dr. Schönrock's investigation was carried on with a polariscope and not with a saccharimeter and it is very evident that he desired to take every precaution to secure accurate results.

In order to do full justice to Dr. Schönrock's work it has seemed best to the writer to quote at length Dr. Schönrock's remarks bearing on this matter, as given in the journal cited above.

"(β) Angaben über die erreichte Genauigkeit bei der Bestimmung der specifischen Drehung des Rohrzuckers.

"Wie im letzten Bericht auseinandergesetzt worden ist, sollte zunächst behufs Ermittelung des alten Hundert punkts der Ventzke'schen Skale bei 17.5° für Natriumlicht die specifische Drehung [α] einer Rohrzucker-lösung bestimmt werden, die bei 17.5° in 100 wahren ccm. (1 ccm = Volumen von 1 g. Wasser bei 4°) 26,003 g. Rohrzucker (wirkliche Masse) enthält.

"Zunächst machte eine scheinbare geringe Zunahme der Drehung einer und derselben Zuckerlösung mit der Zeit einige Schwierigkeit, welche sich erst dann löste, als man dem Verschluss der Röhre eine über die gewöhnlichen Vorsichtsmassregeln weit hinübergreifende Aufmerksamkeit zuwandte. Die Schwierigkeit, ein Verdunsten des Wassers aus der in der Polarisationsröhre enthaltenen Zuckerlösung, zumal bei Temperaturänderungen zwischen 12° und 25°, vollkommen zu verhindern, ist viel grösser, als man gewöhnlich annimmt. Da die Röhre etwa 73 g. Lösung enthält, so ändert das Verdunsten von 1 mg. Wasser die Drehung α um beiläufig 1/60,000 ihres Werthes. Das Verdunsten liess sich erst dann bis auf 1 cg. und weniger reduziren, als man folgendermaas-

sen verfuhr. Die Deckgläschen werden nicht wie gewöhnlich durch übergeschraubte Deckel gegen die Röhre gepresst, sondern mit gerade im Erstarren befindlichen Klebwachs angekittet, doch so, dass sie direket mit den Endflächen der Glasröhre in Berührung bleiben; die in Rechnung zu setzende Verschiebung des Nullpunktes durch die leere Röhre betrug dann nie mehr als ± 30″. Die Füllung der Röhre geschieht durch eine seitliche Oeffnung, die mit einem geschliffenen Glasstöpsel verschlossen werden kann, durch welchen ein Thermometer in das Innere der Lösung hineinragt. Die nunmehr noch eintretende Verdunstung liess sich auf ± 1 mg. ermitteln." * * *

"(γ) Abhängigkeit der specifischen Drehung von der Temperatur.

"Es ist unbedingt erforderlich, regelmässige Wägungen der gefüllten Polarisationsröhre auszuführen, um Gewissheit über die erlangten Resultate zu haben; da nun wegen dieser Wägungen eine Wasserspülung zum Konstanthalten der Temperatur nicht angewendet werden kann, so entstand die Forderung, sich über eine etwaige Abhängigkeit der specifischen Drehung $[\alpha]$ von der Temperatur t Gewissheit zu verschaffen. Bisher wurde stets angenommen, dass $[\alpha]$ gar nicht oder in ausserordentlich geringem Maase mit t variirt, eine Annahme, die sich auf die Beobachtungen von Tuchschmid, Seyffart und Andrews (? F. G. W.) stützte. Das Vertrauen zu diesen Beobachtungen wurde aber bereits bei den im vorigen Bericht erwähnten Vorarbeiten mit einem Saccharimeter ershüttert, weil in die bei Zimmertemperatur zwischen 18° und 20° erhaltenen Resultate nur dann Uebereinstimmung zu bringen war, wenn man etwa $\frac{d[\alpha]}{dt} = -0{,}02$ setzte. Dass dieser Werth von der richtigen Grössenordnung war, beweisen die bisher zwischen 12° und 25° untersuchten zehn Zuckerlössungen, welche für $\frac{d[\alpha]}{dt}$ Werthe ergaben, die ausnahmlos zwischen den Grenzen $-0{,}0151$ und $-0{,}0132$ liegen, im Mittel $\frac{d[\alpha]}{dt} = -0{,}0144$.

"Nimmt also die Temperatur der Zuckerlösung zu, so nimmt der Drehungswinkel ab, erstens weil die Konzentration der Lösung wegen der Volumvergrösserung abnimmt, und ausserdem noch, weil die specifishe Drehung kleiner wird. Da der zweite Betrag ¾ des ersteren beträgt, so darf man da, wo man die Konzentra-

tionsänderungen in Rechnung zieht, auch die Änderungen in der specifischen Drehung keineswegs vernachlässigen."

From this it appears, that in order to guard against evaporation of water from the sucrose-solutions on warming the same, Dr. Schönrock fastened glass-covers permanently on his polariscope-tube. The sucrose-solutions were introduced through an opening provided in the side of the tube, which opening was closed with a ground-glass stopper.

It seems to the writer that the results of Dr. Schönrock can not be accepted as above criticism on account of these very precautions which were taken by him.

Dr. Schönrock himself states that the glass covers of his tube were optically active even when the tube was empty (p. 180).

The effect of stress on the optical behavior of glass is well known. The warming up of the sugar-solutions in the tube must have caused pressure upon the cover-glasses in consequence of the expansion of the fluid confined between them.

In this connection it will be proper to recall attention to the article by Dr. C. Scheibler, Ueber den Einfluss der Deckgläschen für Beobachtungs-röhren bei der optischen Zuckerbestimmung (Zeitschrift des Vereins f. d. R. Z. I. d. D. R., *1869;* Vol. 19, pp. 50–52), and especially to the work of Dr. Paul Degener, Ueber das optische Verhalten der Polarisations Deckgläschen (Zeitschrift des Vereines für die Rübenzucker-Industrie des Deutschen Reichs, Vol. 32, *1882*, pp. 861–865).

Degener found that the glass covers of a polarization-tube, which glasses polarized the light but slightly while the tube was empty, exercised a very pronounced effect as soon as the tube was filled with water or with alcohol. This result was due to the additional pressure which the confined column of fluid exercised upon the glass covers.

The deflections in the plane of polarization which Degener thus produced solely by the pressure of optically inactive solutions on the glass-covers of his polarization-tube ranged from a few tenths of a degree to three degrees Ventzke. In some instances the rotations produced were to the right, in others, in fact in most cases, to the left.

Similar variations in rotation were encountered by Dr. Schönrock. As a rule, he noticed a decrease in the dextro-rotation of his solutions on raising their temperature. This—in view of

Degener's experiments—may well have been caused by the glass-covers of his polarization-tube becoming levo-rotatory in consequence of the pressure exerted upon them through the expansion of the confined solutions.

However, Dr. Schönrock also found that: "the specific rotation in time *increased* by amounts up to 0.044 and this without evaporation having taken place" (*loc. cit.*). It is evident that an increased dextro-rotation of the cover-glasses, caused by pressure, could also have produced this very effect.

Professor Herzfeld, the great German authority on sugar, in an article published in the *Zeitschrift des Vereins der Deutschen Zucker Industrie*, Jan., 1899, referring to Schönrock's formula bearing on the decrease of specific rotation of sugar solutions through an increase in temperature, states that his own (Herzfeld's) experiments, as well as the few observations which have hitherto been published on raw-sugar solutions, are not in particular accord with the views embodied in Schönrock's statement.

In the April number, 1900, of the *Zeitschrift des Vereins der Deutschen Zucker-industrie* (pp. 413–434) Dr. Schönrock has published a detailed résumé of his prior work, which has here been discussed. He has also added the data of some additional experimental work recently undertaken by him.

Dr. Schönrock finds no occasion to change the conclusion he had previously reached; on the other hand, the present writer can find nothing in this new statement of Dr. Schönrock's work which would alter the impression he has gained from a study of the earlier writings of this investigator.

The data which Dr. Schönrock found on testing his polariscope-tubes with pure water, at different temperatures, serve but to emphasize the danger which threatens from the pressure exerted by expanding solutions.

These tests show such wide discrepancies and variations that it would seem impossible to deduce from them any average allowance-factor which could be taken into account in estimating the influence of this source of error on his results. Especially does this appear evident in view of the statement made by Dr. Schönrock himself (p. 421) where he says, that the pressure of the expanding sugar solutions, when experiencing changes of temperature between 10° and 32° C., was so great, that an escape of the solutions at the cover-glasses could not be prevented when these were

held in place by the customary screw-caps and rings of caoutchouc or soft leather, although an empty tube, attached to the middle of the polarization-tube, had been provided to accommodate the expanding solution.

Attention must also be called to the fact that the specific rotatory power of the different sucrose samples which Dr. Schönrock has employed, vary by as much as 0.8, vide 65.8 and 66.6.

No explanation is offered as to the cause of these great variations in the specific rotatory power of the sucrose samples with which Dr. Schönrock has worked and upon the examination of which he has based his conclusion.

One is therefore confronted by the possibility of the presence of some unknown, but optically active substance, or substances, endowed with a rotatory power readily affected by temperature-changes, which also might well serve to cause, or at least to contribute to, the variations observed by Dr. Schönrock.

The latest contribution to the cause of those who hold that temperature exercises an appreciable effect on the specific rotatory power of sucrose is to be found in an article by Professor Harvey W. Wiley of Washington, D. C.

Professor Wiley read this paper before the Third International Congress of Applied Chemistry at Vienna, Austria, in 1898, and also before other scientific bodies. His article has appeared in several journals, among others in the *Journal of the American Chemical Society*, July, 1899, there bearing the title: *The Influence of Temperature on the Specific Rotation of Sucrose and Method of Correcting Readings of Compensating Polariscopes therefor.*

Briefly stated, Professor Wiley's contention is this: Sugar solutions made up and read at temperatures other than the temperature at which the saccharimeter employed in their observation has been graduated, will show readings varying with those temperatures.

The higher said temperatures are above the temperature at which the saccharimeter has been graduated, the lower—so claims Professor Wiley—will be the readings which are obtained.

This lowering of the polarization readings is, according to Professor Wiley, essentially due to two causes:

(*a*) The influence of temperature elevation on the optical value of the quartz-wedges of the saccharimeter employed.

(*b*) The decrease in specific rotation, which—so Professor Wiley

assumes—solutions of sucrose experience through an elevation of temperature.

In the commencement of his article Professor Wiley refers to several investigators whose work, he claims, support his own contention.

As these writings have already been discussed in this paper, it will not be necessary to refer to them again, save, perhaps, to remark that in the light of experience and knowledge gained since most of these researches, cited by Professor Wiley, have been made, it has proved no difficult task to point out their defects and short-comings. In many instances, though not in all, the use of defective saccharimeters has undoubtedly been to blame for some of the peculiar results obtained.

A fundamental defect of Professor Wiley's investigation, so it appears to the writer, is the fact that he has employed as his point of departure in his investigation *a mixture of sucrose and mercuric chloride solutions.*

It is shown in the text on p. 574, that the whole investigation is based on one stock-solution of sucrose, "a thick sirup having almost exactly fifty per cent. of pure sugar and fifty per cent. of water. This sirup was preserved by having added to the water before solution an appropriate quantity of mercuric chloride."

In making a scientific study of the properties of a substance, it is the usual practice and absolutely essential to prepare that substance as pure as possible and if the substance be perishable, *i. e.*, easily changed in composition—to work with it in its most stable form.

Professor Wiley in working with a *solution* of sucrose and in adding to that solution of sucrose a *foreign substance*—mercuric chloride—has certainly placed himself in opposition to all well founded custom and practice in both of the respects indicated.

When we are furthermore informed that the experiments with the above solution extended over a period of at least four days, (April 12th to 15th, inclusive), during which time said solution was exposed to temperatures varying from 4° C. to 40° C., it seems incredible that Professor Wiley should have succeeded in "having an absolutely unvarying quality of sugar solution" (p. 574) such as he desired to employ in his investigation.

The writer's conviction on this point is based—not on surmise, but on experience. To test the matter he prepared a 50% solu-

tion of pure white sugar-liquor and of this placed 400 cubic centimeters into a 500 cubic centimeter flask. After the specific gravity of this solution had been very carefully determined by a pyknometer, the flask was well corked and set aside for 24 hours in a place the temperature of which throughout that time was practically constant at from 23° to 24° C. The specific gravity of this solution at the beginning of the experiment was 1.23390. Twenty-four hours later it was 1.23565. The first of these specific gravity values corresponds to 50.20° Brix, that is to say to 50.2 per cent. of sucrose, while the second specific gravity value represents 50.5 per cent. In other words, this sucrose solution had changed its sugar content by 3/10 of one per cent. through evaporation of water into the air space above the solution.

Professor Wiley worked entirely with one stock-solution, of which double the normal weight—*i. e.*, 52.096 grammes—were weighed off for each determination. It appears, that all of the experimental data obtained by Professor Wiley were secured on thirty-eight solutions. Observations were made at eight different temperatures; in six of these determinations five solutions were used, in the remaining two instances four solutions were employed.

As readings on all sets were made in triplicate, the total number of readings made on the thirty-eight solutions amount to four hundred and thirty-six.

Four hundred and thirty-six readings made on thirty-eight solutions would represent on the average, eleven or twelve readings per solution, a number which should be ample to determine accurately the reading value of the solution examined.

Professor Wiley says: "In each case unless otherwise noted, five solutions were used and each solution was read four times, or more *if there were errant readings*, and *the mean of the four concordant readings* taken as representing the true reading."

Referring to the words underscored in the above sentence, by the present writer, it is, of course, necessary, or least desirable, to exclude from a given series any and all observations which can be truly considered as unsatisfactory. However, as Lupton says, in his *Notes on Observations* (p. 84): "The rejection of doubtful results is a most delicate and difficult subject. Great care should be exercised, that it never takes place consciously or unconsciously in favor of a preconceived theory by which the judgment is very liable to be biased."

If "the four concordant readings" were selected to secure "the true reading," *simply because they were concordant*, serious exceptions might well be taken to this procedure.

In order that a "mean" shall be correct it is necessary that the data from which it is obtained shall be strictly comparable *inter se*.

Professor Wiley, however, "in order to secure a better check on the readings," secured his sets of readings as follows: he obtained one set with the white-light telescope, one set with the yellow-light telescope and one by inserting in the instrument a left-handed quartz plate of known value.

Now it is a well-known fact that the nature and the color of the light employed in making observations on a polariscope, materially affect the results obtained. But Professor Wiley takes as his mean polarization (p. 580), the average values of *all* the results obtained. The objection here raised seems especially pertinent when it is borne in mind that the "yellow light" values were partially secured in three different ways, viz: by means of a crystal of potassium bichromate, by a yellow glass plate and by a solution of potassium bichromate. Even the source of light varied, for although generally gas was used, yet kerosene light was employed in some of these determinations.

Professor Wiley himself seems to be aware of this cause of disturbance here referred to, for he says (p. 575):

"The variations in the readings of the standard quartz plates which will be noticed in the data here and following, *aside from the nature of the light*,* are due to differences in setting the double quartz wedge compensation and not to changes in rotatory power."

Attention is next invited to the "table of corrections for polarizations made with quartz-wedge compensating polariscopes at temperatures other than the standard temperature of 17.5°C.," which is given on pp. 581, 582 of Professor Wiley's article.

These "correction-factors" cover the temperatures from 4° C. to 40° C. "for sugars of different content of sucrose" (p. 580).

This range of sucrose content extends presumably from 100% to 75 %, for the table exhibits values from 100° to 75° Ventzke.

These values are all based on observations made at eight different temperatures on solutions of "pure sugar" (p. 580).

Has Professor Wiley any evidence to show that sugars containing as high as 25 % of matter *not sucrose*, behave exactly analo-

* Italics by F. G. W.

gous to a sugar testing practically 100 % ? If he has such evidence, it certainly does not appear in the article under consideration. Without proof to that effect, the broad generalization here made —the basing of 962 "correction-factors" on observations made on *one* stock solution of pure sugar at eight different temperatures— can hardly be expected to inspire confidence in regard to its intrinsic merit.

Professor Dr. A. Herzfeld in the *Zeitschrift des Vereins der Deutschen Zucker Industrie*, January, 1899, p. 19, says: "I am occupied with a continuation of the work, inasmuch as I am first of all determining whether raw sugar polarizations give, at different temperatures readings which correspond to the theoretical values calculated for sucrose by means of known formulæ." And caution in this respect seems particularly to be commended when one recalls the classic research of R. Nasini and E. Villavecchia, Sul peso normale pei saccarimetri, Roma, 1891 (On the normal weight of polariscopes). In this investigation of 78 samples of *pure* sucrose, prepared from all sorts and kinds of raw sugars, refined sugars, molasses, etc.—the specific rotatory value of sucrose at 20° C. was found to vary within rather wide limits.

The Imperial Technical Institute at Berlin is, according to late accounts, even now engaged in preparing for a series of determinations of the specific rotatory power of chemically pure sucrose. Therefore, to announce the extent to which the specific rotatory power of sucrose is affected by changes in temperature— per degree Centigrade—when the *constant* which is *assumed* and *presumed* to suffer such change, has not even been definitely and indisputably determined, is an undertaking which can certainly not hope to escape challenge and criticism.

According to Professor Wiley, the use of correction factors is called for regardless of the fact that the slight, unavoidable lowering in the reading of a sugar solution, caused by the influence of an elevation in temperature on the quartz-wedges of the saccharimeter, is offset, and more than offset in practical sugar-polarizations, by the unavoidable concentration of the sugar solutions which is caused by the precipitate formed in clarifying. The numerical value of Professor Wiley's "correction factors" is proportionate to the temperature at which the polarizations are made.

To test this system of correction-factors strictly on its merits, a

number of tests were made with practically pure sucrose (Polarization = 99.98). Thus any and all undue concentration of the solutions examined was avoided as no clarifying reagent was needed in preparing them for observation in the saccharimeter. This work was carried on by several observers, the writer among the number. The solutions were all most carefully prepared in verified Mohr flasks and were polarized at the same respective temperatures at which they were prepared. Some of the observers used a sensitive color-saccharimeter, while the others employed a Schmidt & Haensch half shadow instrument. The data are given in the following table:

Test No.	Reading observed.	Temperature, degrees Centigrade at which solution was prepared and the readings taken.	Wiley's "Correction-factor" derived from his table. To be added to the reading found.	"Corrected" Polarization according to Professor Wiley's data.
1	99.90	23.0°	0.18	100.08
2	99.85	24.5°	0.22	100.07
3	99.90	25.0°	0.24	100.14
4	99.90	25.7°	0.26	100.16
5	99.90	26.5°	0.28	100.18
6	99.90	27.5°	0.32	100.22
7	99.90	29.0°	0.37	100.27
8	99.85	30.0°	0.40	100.25
9	99.80	31.7°	0.45	100.25
10	99.80	33.0°	0.50	100.30

From this record it clearly appears that the use of Professor Wiley's so-called "correction-factors" would ascribe to pure sucrose—at the temperatures at which the experiments were made—a polarization of over 100 per cent. The excess over and above 100 per cent. will be seen to keep pace with the rise of the thermometer; further comment is certainly unnecessary.

In giving his table of the "Specific Rotatory Power of Sucrose at temperatures ranging from 4° to 40° C." on page 594 of his article, Professor Wiley states: "The observations were made with a triple-field saccharimeter, the readings being converted to angular degrees by use of the factor 0.3462."

These "equivalent angular degrees with sodium light" appear in Professor Wiley's table and are made the basis of the various values of $[\alpha]$ which he determined for different temperatures.

In chosing his instrument, his source of illumination, etc., Professor Wiley has put aside wholly the cautioning and advice of Professor Landolt and of Dr. Schönrock. Thus Landolt writes: (*Zeitschrift des Vereines für Rübenzucker Industrie*, 1888, Vol. 38,

p. 32): "One will therefore do better not to employ instruments with quartz-wedge compensation and illumined by white light for the determination of specific rotatory values $[\alpha]\ D$, but to always use for this purpose regular polaristrobometers."

Dr. Schönrock says, in speaking of making observations with white light and half shade saccharimeters (see Landolt, *Das Optische Drehungsvermögen Organischer Substanzen*, II. Ed. 1898, p. 378):

"If the rotation obtained in Ventzke degrees be multiplied with the factor 0.347 [Professor Wiley uses the factor 0.3462] one can at least say, that the product so obtained, the angle of rotation in cirular degrees for sodium light, is accurate to within *about two or three per cent.*"*

Dr. Schönrock then continues: "There is no sense in seeking to determine for individual substances more accurate factors of calculation (Umrechnungs factoren) *as accurate measurements without material systematic errors can never be made with a saccharimeter,** on account of rotation dispersion, influences of temperature and the changeability of the rotation due to the illumination and the color-sense of the observer. Therefore, if it is possible, avoid the use of a saccharimeter and obtain for illumination of a polarizing apparatus, intense sodium light, the preparation of which, moreover, causes but slight trouble."

Thus there will hardly be need for "the numerous series of observations" which Professor Wiley deems requisite, to determine the cause of the material differences in the data tabulated on p. 594.

It does seem surprising, however, that Professor Wiley should be willing to base on the data he has tabulated the final conclusion of his investigation, the claim that: "for each change of one degree in the temperature the polarization of a pure sugar on an instrument with a Ventzke scale suffers a change of 0.01494° (this is = 0.005172 circular degrees) due exclusively to the change in the specific rotatory power of the sugar solution" (p. 593).

Consulting his table (p. 594) it is seen that the differences per 1° C. in the specific rotatory power of sucrose differ amongst themselves by as much as 0.0229° Ventzke (= 0.00793 circular degrees) [*vide:* 0.01460 and 0.00667]. Professor Wiley's factor is therefore, so it appears, based upon a series of determinations—

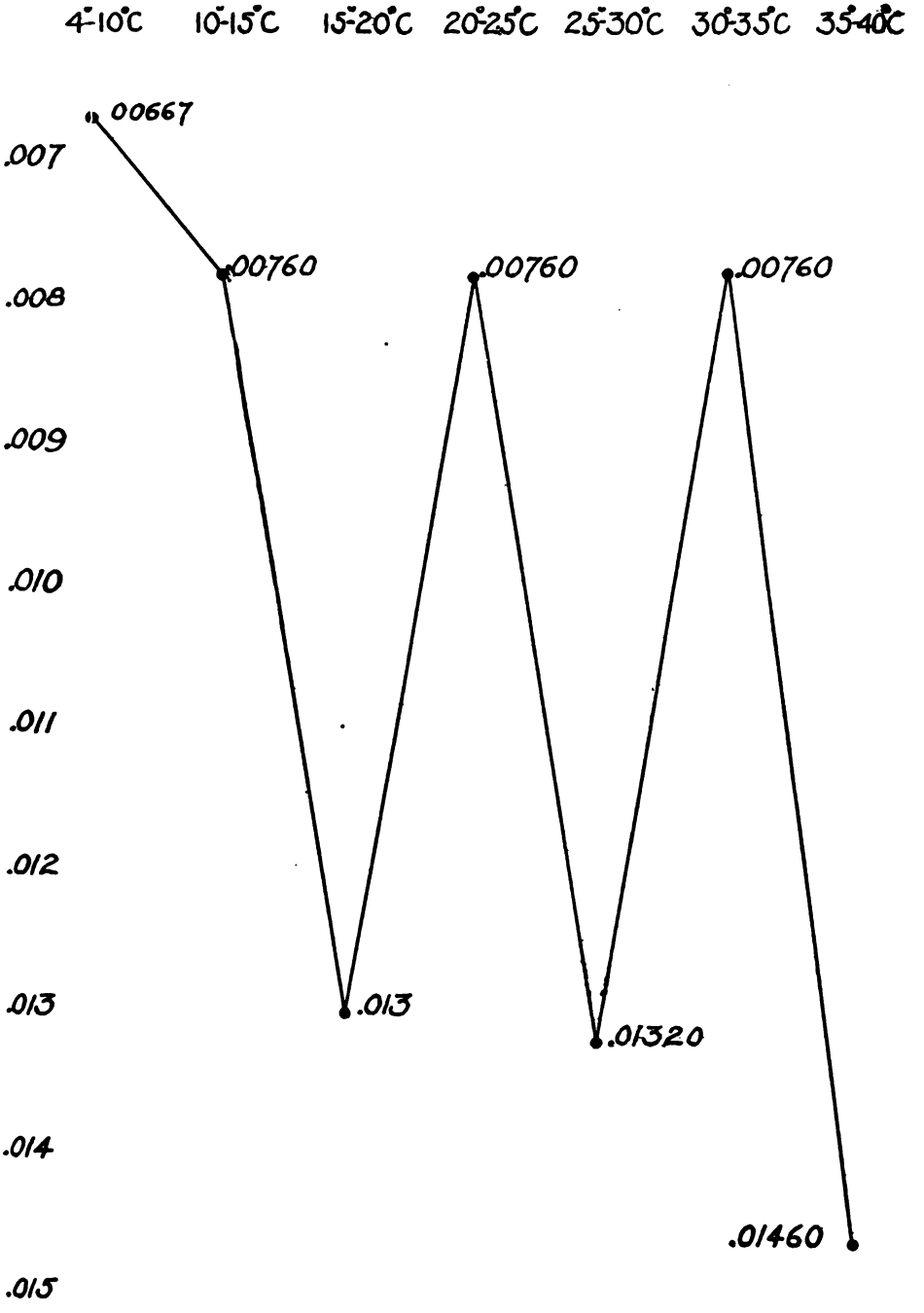
* Italics by F. G. W.

made upon *one* original stock solution of sucrose—which determinations exhibit amongst themselves differences per degree Centigrade to the extent of very nearly one hundred and nineteen per cent.

This marked discrepancy has been noted and commented upon also by others. Thus, in the notice of Professor Wiley's article which appeared in *The Analyst*, Vol. 24, No. 284, November, 1899, p. 288, the reviewer writes, in referring to the variations in the specific rotatory power of sucrose due to temperature-influence, as found by Wiley: "It appears, however, that the variations are not uniform, the rate of decrease being greater (nearly double), between 15° and 17.5°; 20°–25°, and 30–35° C., than elsewhere in the series."

The diagram on the following page depicts graphically the differences of the specific rotatory power of sucrose per degree Centigrade, at different temperatures, as determined by Professor Wiley's experiments.

The peculiar character of the plotted line, showing such marked alternations of elevations and depressions, is certainly not calculated to dispel the grave doubts expressed as to the value of the experimental data on which it is based.


4°-10°C
10°-15°C
15°-20°C
20°-25°C
25°-30°C
30°-35°C
35°-40°C
.00667
.00760
.00760
.00760
.013
.01320
.01460
.007
.008
.009
.010
.011
.012
.013
.014
.015

A critical survey of all of the literature thus far examined has therefore failed to disclose a single, indisputable demonstration of the correctness of the contention that temperature exercises an influence on the specific rotatory power of sucrose.

On the other hand, evidence to the contrary exists in abundance. It appears, in fact, that a *majority* of the scientists who have carefully studied the question have reached the conclusion that the specific rotatory power of sucrose is a constant. In their work some have employed polariscopes, others have used saccharimeters.

It would be impracticable to discuss here in detail all of these investigations. The following quotations, arranged in the chronological order of their publication, will prove sufficient to express the views of their authors on the matter at issue.

1842. Mitscherlich, E. Gesammelte Schriften, Berlin, 1896.

"With some substances the temperature has no influence; for instance, with cane sugar" (p. 554).

1843. Ventzke, K. Journal für Praktische Chemie. Vol. 28.

"Influence of temperature on circular polarization. In cane-sugar solutions of 25% strength I had frequently made the observation that a marked elevation of temperature had no influence upon its deflection to the right" (p. 101).

"Hence I feel that I am justified in assuming for the practical ends here pursued, as only sugars are concerned which have a dextro-rotation, that in any case, *the temperature during observation* has no influence, and hence can be left out of consideration" (p. 103).

1858. Arndtsen, A. Annales Chim. Phys., Vol. 54.

Arndtsen in studying the molecular rotatory power* of sugar solutions with various wave-lengths of light, says:

"One sees that the values found, agree for all wave-lengths in such a manner that it is indisputable that the molecular rotatory power of sugar, is strictly a constant" (p. 408).

1860. Berthelot, M. Chimie Organique fondée sur la Synthèse, Paris.

Under the caption *Saccharose* the author states:

"Its rotatory power is right handed. * * * It does not vary appreciably with the temperature" (Vol. 2 p. 255).

* Molecular rotatory power is the value obtained by multiplying the specific rotatory power of an optically active substance by its molecular weight divided by one hundred. (Landolt, Opt: Dreh: Org: Subst: pp. 5 and 6.)

1870. Tuchschmid, C., Journal für Praktische Chemie, Vol. 110, Bd. 2.

This investigation was made in the laboratory of Professor H. Landolt. Tuchschmid writes:

"Therefore, the statement may be made with positiveness: The molecular rotatory power of pure sugar solutions is independent of the temperature" (p. 245).

The range of Tuchschmid's experiments was from 10.4°C. to 40.5°C., a range of 30.1°C.

1875. Hesse, O., Liebig's Annalen der Chemie (Vol. 176).

In that part of his investigation bearing on sucrose the investigator says:

"The solution of the sugar took place in the cold, although warming of the solution did not exert a deleterious effect upon its rotatory power" (p. 97). Hesse's experiments were carried on at temperatures between 15°C. and 25°C.

1878. Von Wachtel, A. O., Oester: Ung: Zeitschrift für Zucker-Industrie, etc. (Vol. 7).

Von Wachtel finds that the temperature exercises no influence on the specific rotation of sucrose. Reference to his work and demonstration of this fact have previously been given. See also Von Lippmann "Die Chemie der Zuckerarten," 1895, page 672.

1882. Von Lippmann, E. O., Die Zuckerarten und ihre Derivate.

"Temperature is without influence on the rotation of sucrose" (p. 117).

1890. Seyffart, J., Annalen der Physik und Chemie Neue Folge, Band 41.

Seyffart's classic research, made in the laboratory of Professor Wiedemann, at Leipzig, determined that for a 20% sucrose solution the rotations for the seven lines of the spectrum were identical at the temperatures of 15°C. and of 65°C. It proved that the specific rotatory power of sucrose is a constant for that range of 50° Centigrade. Seyffart says:

"The observation of Tuchschmid, with regard to *the constancy of the specific rotatory power of sucrose solutions at different temperatures*, is confirmed by the present investigation and is supplemented in regard to its validity *for all colors of the spectrum.* Hence *dispersion also is independent of temperature*" (p. 129).

1893. Josse, A. Bull. de l'Ass. des Chimistes, etc., Vol. 11.

"Desirous on my part to make a few experiments on this matter, I undertook a series of observations without seeking to attain to mathematical exactness like the preceding authors, but confining myself simply to the precautions of ordinary practice. My conclusion is that a difference in temperature of 25°C., has no more than a negligible influence upon a sugar solution of the normal weight of 16 Gr. 20" (p. 261).

1897. Von Lippmann, E. O. Zeitschrift des Vereins für Rübenzucker-Industrie, Vol. 47, Tech. Theil.

"It is known to you that temperature does not effect a change in the rotatory power of cane-sugar as such" (p. 651).

In conclusion there shall be quoted at length some remarks made by Dr. Seyffart in a convention of the Sächsisch-Thüringischer Zweigverein der Deutschen Zucker-Industrie at Halle a. S., Germany, which took place December 15, 1898.

This statement is one of particular interest and importance because it so clearly points out and emphasizes the error in polarization resulting from the employment of various sources of light, a matter upon which comment has already been made in an earlier part of this paper while discussing the investigation of Professor Wiley.

1898. Seyffart, J. Die Deutsche Zucker-Industrie, No. 52, Beilage 1.

"There are principally two causes which bring about the differences in analyses (of sugar) that have been reported. On the one hand it is the influence of the temperature on the polarizing apparatus caused by the heat rays which emanate from the source of light and which cause stress effects in the mechanical and optical parts of the polariscopes in connection with the various screw-fastenings and cementings of the same; these must bring about a deflection of the light rays.

"In order to avoid this source of error I have always moved the polarizing apparatus as far away as possible from the polarizing lamp—at least 5 to 7 inches; furthermore, after every observation the apparatus is to be turned a little away from the light, for which reason the instruments which can be turned are more practical than those which are fixed in their position.

"The second and very important cause of the differences in polarizations lies in the various sources of light which are employed

in the various laboratories. In part petroleum light is used, in part gas light, in part incandescent gas light, in part electric incandescent light.

"Not one of these white lights possesses, when measured in the spectroscope, the same brightness of spectrum in its various parts and the mean effect of these various kinds of light is by no means identical with respect to the rotation of the plane of polarization.

"How can one expect absolutely identical degrees of rotation with such various sources of light when we well know that, for instance, petroleum light contains many more red and fewer violet rays, while the spectroscopic composition of the incandescent gas light is rather the reverse, and although we know that the angle of rotation for violet rays is much larger than for red rays?

"The resultant of the varicolored rays which are united in white light can hence never be absolutely identical for the various sources of light, and to secure a better agreement in the results of polarization, it is, hence, necessary to come to an agreement as to some source of light which shall be used once and always, and in all places."

Speaking of some recent observations concerning the increase of the angle of rotation for sugar solutions by temperature, Seyffart calls attention to his investigations which he had previously made in the physical laboratory of Professor Wiedemann in Leipzig, and according to which the angle of rotation remains absolutely constant even up to a temperature of 60° Centigrade (see reference previously given). Seyffart says:

"I will admit that it may be possible that one can perhaps nowadays work even more accurately with the polarizing instruments which have in the meantime been perfected, but which are also very complicated.

"However, an increase of the angle of rotation up to 0.6° I consider to be based upon error, for at that time I was abie to work with an accuracy far below 0.1°, and the total apparatus which I used precluded absolutely the slightest warming of the parts of the polarization apparatus, so that solely and alone the influence of the temperature of the sugar solution could affect the angle of rotation and be observed" (p. 1915).

In conclusion the present writer would respectfully submit his own experimental investigation of the problem.

Although it appears preferable that critical studies of this matter

should be effected by means of polariscopes and their proper appurtenances rather than by saccharimeters, yet it is undoubtedly a matter of great practical importance to determine whether, or no, variations in the specific rotatory power of sucrose—*in case such should be induced by variation of temperature*—could make their influence felt on, and could be determined by, saccharimeters.

To put this question to a most thorough test a series of determinations was made with a sample of pure sucrose. The work was carried on by Messrs. John A. Sherer, Edward Wolfbauer, Edward C. Brainerd, Dr. J. A. Deghuée, and the writer.

Two saccharimeters, the one a sensitive color, the other a Schmidt & Haensch half-shade instrument, were used; all possible precautions and care were taken to ensure accuracy.

Each solution was polarized at the temperature at which it was prepared, and the saccharimeter was also kept at that same temperature while the observations were being made.

The sucrose employed was most carefully prepared from a high grade of refined sugar. Its polarization was 99.98 at 20° C. This value was determined by Professor Dr. Alexander Herzfeld, Berlin, Germany, to whom a sample of this sucrose—in a glass-jar, under seal, had been forwarded.

The results secured in a dozen experiments are given in the following table:

Test No.	Reading observed on Saccharimeter.	Temperature (Centigrade) at which the solution was prepared and observed in Saccharimeter.	Jobin's correction (Formula: Pol.+ [0.00016 T]N to be added to Saccharimeter readings.	Polarization referred to the normal temperature 20° C.	Variation from the true value of the sucrose 99.98.
1	99.90	23.0°	0.04795	99.95	—0.03
2	99.85	24.5°	0.07189	99.92	—0.06
3	99.90	25.0°	0.07992	99.98	0.00
4	99.90	25.7°	0.09110	99.99	+0.01
5	99.85	25.7°	0.09106	99.94	—0.04
6	99.90	26.5°	0.10389	100.00	+0.02
7	99.85	27.0°	0.11183	99.96	—0.02
8	99.90	27.5°	0.11988	100.02	+0.04
9	99.85	29.0°	0.14378	99.99	+0.01
10	99.85	30.0°	0.15976	100.01	+0.03
11	99.80	31.7°	0.18682	99.99	+0.01
12	99.80	33.0°	0.20758	100.00	+0.02

Accepting Professor Herzfeld's figure 99.98, as the true polarization of this sucrose at 20° Centigrade, it will be seen that the polarization determined at the temperatures given—ranging from 23.0°C. to 33.0°C.—vary by only a few hundredths of a degree Ventzke.

Placing the limit of accuracy attainable on each of the saccharimeters used, the one a color—the other a half-shade instrument, at ± 0.10° Ventzke, it will be noted that with one single exception (Test No. 2), the variation from the accepted standard value is *less than one-half of a tenth degree Ventzke.*

The average of all the twelve polarizations referred to the normal temperature of 20° Centigrade is 99.98, a figure identical with Professor Herzfeld's value, although the individual polarizations from which this average value has been drawn, were determined at a dozen different temperatures, extending over a range of ten degrees Centigrade.

This would seem to be satisfactory evidence and sufficient to establish the conclusion that—Jobin's correction being applied—solutions of a pure sucrose prepared at various temperatures and polarized at the temperatures at which they have been prepared, will return identical polarizations.

Confirmatory evidence of the justice of this claim has furthermore been secured by the writer by means of a very sensitive and accurate double-wedge compensation saccharimeter, a half-shade instrument, built to order by Julius Peters, of Berlin.

This saccharimeter was examined and certified to as correct by Professor Dr. A. Herzfeld, Director of the Chemisches Laboratorium, *Verein der Deutschen Zucker-Industrie.*

One of the special and, it is believed, unique features of this instrument is the device whereby its quartz wedges are mounted without wax or cement; they are held in place by delicate plates and plate-springs and thus escape all danger of stress which may be induced by variations of temperature and which may lead to very serious errors in the results obtained in such instruments. (See Herzfeld, Ueber den Einfluss der Temperatur auf die Angaben der Saccharimeter. *Zeitschrift des Vereins der Deutschen Zucker-Industrie*, 1899, Tech. Theil, pp. 1–20, and Wiechmann, The Optical Behavior of Quartz under Stress. SCHOOL OF MINES QUARTERLY, 1899, pp. 267–279.)

All of the weighings of the sugars examined in this investigation were made on a correctly adjusted and delicate analytical balance, indicating tenths of a milligramme.

The sugar solutions were all prepared in Mohr flasks which had been carefully standardized; these solutions were always made up at the temperature indicated by a Schmidt & Haensch thermome-

ter (range 8° C. to 34° C., divided into tenths of a degree), which had been kept in the trough of the saccharimeter for at least twenty-four hours prior to and up to the time the polarizations were made. The temperature thus indicated was accepted as representing the temperature of the saccharimeter.

The temperature of the room in which all of the work was done, that is to say, in which the sugars were weighed, the solutions prepared and polarized, was always identical with, or, at least, in very close agreement with the temperature of the saccharimeter.

The source of light was in all instances the same. It was furnished by a Hink flat triple-burner for gas. The light passed through a plane glass disk in the lamp cylinder and then through 30 millimetres of a solution of potassium dichromate—strength 6 per cent.—before it entered and traversed the sugar solution under observation.

All of the work in this investigation was done by, or under the immediate supervision and control of, the writer. To his able assistant, Mr. James Kelly, he would here express his appreciation and thanks for valuable services rendered.

All readings were taken by two observers.

In some instances the *first* reading of each observer was discarded; with this exception, *every* reading obtained has been recorded and the results reported are the actual means of *all* observations secured.

Correction for the alteration in value of the quartz-wedges of the saccharimeter, caused by alteration in temperature, has been effected by Jobin's formula.* Pol: + [0.00016 T]N.

Before proceeding with an experiment the exact state of adjustment of the saccharimeter was always ascertained by means of the control-wedge of the instrument, by means of standard quartz plates kept at the same temperature as the saccharimeter, or, by both of these devices.

In every instance the rotatory values of the respective sugars examined were, at different temperatures, practically identical. Thus one of them showed at:

17.5° C. a polarization of 99.96° V.
22.0° C. " " " 99.94° V.

Another exhibited at:

20.0° C. a polarization of 99.79° V.
23.0° C. " " " 99.78° V.

* *Zeitschrift des Vereins für Rüben-zucker Industrie*, 1898 (p. 835).

A third sample, which, when examined in the saccharimeter with which all these tests were made, showed a polarization of 99.61° Ventzke at a temperature of 26.6° C., returned the identical polarization at a temperature of 33.3 C., when independently examined by another observer and in another saccharimeter, the adjustment of which had been controlled by means of the former instrument.

To illustrate the character of the work done, there shall be recorded *in detail* the results obtained with one of the sugars examined.

This particular sample was prepared by washing one kilogramme of a high grade refined sugar with two kilogrammes of absolute ethyl alcohol, the sugar being then dried for 24 hours at a temperature between 57.0° C. and 60.0° C.

This sugar was examined for the presence of raffinose, and the *absence* of this substance was established, as appears from the data obtained:

Direct polarization	99.57.
Polarization after inversion	99.63.

This sugar was also subjected to a most careful gravimetric examination for invert sugar. Twenty (20.0) grammes of the sugar were used in this determination, and 0.04 per cent. of invert sugar were found.

Determinations of the polarization of this sugar were made at 21.5° C., 26.0° C., 27.5° C., 30.5° C., 32.5° C.

The data obtained were the following:

No. I.

Sugar-solution prepared at			21.5° C.
Temperature of saccharimeter during observations,			21.5° C.
Temperature of solution during observations,			21.5° C.
Reading on solution by:	W.	K.	
	99.50	99.50	
	99.50	99.50	
	99.40	99.45	
	99.50		
Mean:	99.475	99.483	
Mean of all readings taken			99.48
Saccharimeter too low			0.05
Jobin's correction			0.02
Polarization of solution at 21.5° C. =			99.55

No. II.

Sugar-solution prepared at	26.0° C.
Temperature of saccharimeter during observations,	26.0° C.
Temperature of solution during observations,	26.0° C.

Readings on solution by:

	W.	K.
	99.45	99.50
	99.50	99.50
	99.45	99.45
	99.40	99.50
	99.40	99.50
	99.50	99.45
	99.50	99.45
Mean:	99.46	99.48

Mean of all readings taken	99.47
Saccharimeter in perfect adjustment	0.00
Jobin's correction	0.09
Polarization of solution at 26.0° C. =	99.56

No. III.

Sugar-solution prepared at	27.5° C.
Temperature of saccharimeter during observations,	27.6° C.
Temperature of solution during observations,	27.5° C.

Readings on solution by:

	W.	K.
	99.45	99.45
	99.50	99.45
	99.50	99.45
	99.50	99.45
	99.40	
	99.40	
	99.45	
Mean:	99.457	99.45

Mean of all readings taken	99.45
Saccharimeter in perfect adjustment	0.00
Jobin's correction	0.12
Polarization of solution at 27.5° C. =	99.57

No. IV.

Sugar-solution prepared at 30.5°C.
Temperature of saccharimeter during observations, 30.5°C.
Temperature of solution during observations, 30.5°C.

Readings on solution by:

	W.	K.
	99.40	99.40
	99.50	99.40
	99.50	99.40
	99.35	99.45
	99.40	99.40
	99.45	99.40
	99.40	99.40
	99.40	99.40
	99.40	99.40
	99.50	99.40
Mean:	99.43	99.40

Mean of all readings taken	99.41
Saccharimeter in perfect adjustment	0.00
Jobin's correction	0.17
Polarization of solution at 30.5°C. =	99.58

No. V.

Sugar-solution prepared at 32.5°C.
Temperature of saccharimeter during observations, 32.2°C.
Temperature of solution during observations, 32.5°C.

Readings on solution by:

	W.	K.
	99.30	99.40
	99.40	99.40
	99.40	99.40
	99.40	99.40
	99.40	99.40
	99.35	99.40
	99.40	99.40
Mean:	99.38	99.40

Mean of all readings taken	99.39
Saccharimeter in perfect adjustment	0.00
Jobin's correction	0.19
Polarization of solution at 32.5° C. =	99.58

Making a resumé of these results it appears that the polarization of this sugar obtained:

At 21.5°C. = 99.55
" 26.0°C. = 99.56
" 27.5°C. = 99.57
" 30.5°C. = 99.58
" 32.5°C. = 99.58

The limit of accuracy attainable with the excellent saccharimeter employed in these observations is probably ±0.05° Ventzke.

The *maximum* difference between any two of the values found is 0.03° Ventzke.

In other words, all of the polarizations obtained under the stated conditions are virtually identical.

These results, in perfect agreement with those previously given, clearly and undeniably lead to the conclusion that, *under the practical working conditions existing in technical sugar analysis, the specific rotatory power of sucrose is a constant.*

THE COURSE IN ARCHITECTURAL PRACTICE.

By C. P. WARREN, A.M.

It is an open question how prominent a part the practical side of the profession should occupy in the curriculum of a professional school. The obvious fact that it is easier to acquire theoretical knowledge within the walls of a schoolroom and practical knowledge without, is not a sufficient reason for neglecting practice altogether. Indeed, almost all schools recognize this and include more or less of practice in their courses. Some of it is absolutely necessary, not only for the sake of illustrating theoretical principles, but also because it is well to make a survey of the whole field before taking up the details and such a survey is more practicable in a school than in the offices. Thus engineering schools have summer classes in surveying, mining and shop work; law schools have their mock trials and medical schools their clinics and public operations. In architectural schools the practical side of architecture is covered in a variety of ways, sometimes by lectures on architectural practice, sometimes by exercises in the preparation of office drawings and specifications, sometimes even by practical shop work in carpentry, masonry, plumbing, etc. In most schools, however, so little time is available for such work that the ground can be covered only in the most cursory manner. It is believed that the course in Architectural Practice as administered at Columbia goes more into details than is usual in this country. This course has been developed in its present shape because it was found that it took our graduates six months in an office to learn enough office work to make themselves useful. We thought we could teach them that much in less time ourselves.

The practice as distinguished from the theory of Architecture comprises the preparation of the working drawings and the superintendence of the various operations and processes by which these are carried into execution. The preparation of the drawings and specifications demands familiarity with the prevailing forms of construction and with the nomenclature and character of the multitudinous objects of carpentry, masonry, plumbing, painting, glazing, hardware, etc. The superintendence of a building in process of erection requires, furthermore, acquaintance with the names and properties of all sorts of building materials and apparatus, and with

the methods for testing them: a kind of knowledge which, while covering the same ground with that of the specifications, is quite distinct in character. These two departments of Architectural Practice are accordingly in the Columbia School recognized and covered by two distinct courses of lectures: one on Specifications and the other on Building Materials and Superintendence.

In its present shape the course in Specifications was started in 1893. Its object is to familiarize the students with the ordinary forms of contracts and specifications, with various details of construction, and with general office management. A model specification has been prepared which embraces all of the particulars likely to occur in different kinds of buildings. It was carefully compiled from the best attainable specifications of private dwellings, churches, hospitals, warehouses, public buildings, etc., the best architects freely putting their specifications at our disposal for the purpose. It thus embraces the experience of men engaged for many years in active professional work. This specification is read and explained to the class and the details of construction which it calls for are illustrated by diagrams and by copies of working drawings. The diagrams, like the specifications, cover the whole field of building operations. They are nearly two hundred in number, and they illustrate not merely details of construction, but various building operations such as shoring, underpinning and pile driving. The model specification has been printed and is distributed to the class, a page or two at a time, before each lecture. The students are required to copy it in a special book, to take notes of the explanations and to make sketches of the diagrams. The alternate pages of the Specification Book are left blank for future additions. The more important diagrams have been reduced to convenient size and are also printed and distributed. A page of the model specification and reproductions of some of the diagrams are given at the end of this article.

The lectures on Specifications treat first, of the general law of contracts, the various forms of contracts in use, the different ways of preparing plans and specifications for estimates and the advantages and disadvantages of each, the instructions to bidders, the rules to be observed in writing specifications and the proper form for the general clauses; secondly, of the specific clauses illustrating the various details of construction. These lectures are grouped under the heads of Carpentry, Masonry, Structural Steel and Iron Work and Plumbing and Drainage of Buildings.

I. Under the head of Carpentry are explained the ordinary methods of framing and the advantages and disadvantages of each, the preparation of framing plans and elevations and the details of all of the joints and connections. Besides the diagrams and working drawings these lectures are further illustrated by models. A model of a regular mortise and tenon frame, one-eighth full size, but complete to such small details as hard wood pins, joints and bridle irons, is built up before the class so that each student sees not merely the completed frame, but the progress of putting it together. In addition to this full-size models are also shown of all of the principal joints and connections. Then the framing of roofs is taken up in the same way. After this the minor details of carpentry, sheathing, flooring, outside and inside finish, and the construction of doors, windows and frames are specified and explained.

The subject of slow burning or mill construction follows and is illustrated by lantern slides showing factory buildings at different stages in the development of the system, and also by diagrams, working drawings and models. The models are all one-eighth full size and show the general layout of factories and mills and the details of their construction. One of them was made under the direction of the president of the Boston Manufacturers Mutual Fire Insurance Company and illustrates the methods recommended by that company. The application of the principles of slow burning construction to domestic architecture is also explained. The last lectures given under the head of Carpentry are devoted to the various kinds of roofing employed, shingles, slates, tiles, tin, etc.

In order to make the present methods of building more fully understood, the history of each operation is gone over whenever possible. The mediæval methods of framing, for instance, are first explained and their influence upon the earlier colonial frames is traced. Then the evolution of mortise and tenon framing is shown and finally of balloon framing. A comparison between the methods in vogue in different countries and in different sections of this country is made whenever practicable.

II. Under the head of Masonry are included; firstly, by the preliminary operations of surveying, excavating and draining, sheet piling, shoring and underpinning; secondly, foundations; stone, brick and concrete footings, inverted arches, I beam grillage, piles and pneumatic caissons. A large collection of plans of the foundations of notable buildings, such as the St. Paul, Havemeyer, New

York Life, American Tract Society and other buildings, has been made. Thirdly, the superstructure; rubble stone, brick and cut stone walls and piers, chimneys, etc., are taken up and discussed. Cut stone masonry is illustrated by specimens of stone showing all of the facings in use and also the implements for making them. Finally, plastering, fireproofing and the use of terra cotta complete the list of building operations given under this head.

III. The specification for Structural Iron and Steel Work includes the entire subject of modern steel skeleton construction. This is a subject which is neglected even in many engineering schools except on the matter of girders and roof trusses. The reasons for this are that the subject is so modern a one that most of the information is confined to articles published in the technical journals and that the methods are continually changing. Since this course was first given it has already had to be twice rewritten in order to keep up with the times.

This specification begins with the preliminary mill operations, punching, drilling, reaming, assembling, bolting and riveting. Then come the details of construction such as the various forms of bases, cast iron and built-up columns, column connections, beams, girders and lintels, framing, connections and wind bracing. The advantages and disadvantages of each form of column and connection are explained, and full size sections of built-up columns and models of connections are shown.

IV. The final lectures are devoted to the Plumbing and Drainage of Buildings and to the different methods of disposing household refuse. The requirements of the New York City Board of Health are taken as the basis of this specification and it is illustrated by a model showing the plumbing of an ordinary city house. Next winter additional lectures will be given on the ventilation of various kinds of buildings, private houses, schools, theatres, hospitals and public buildings, and also upon heating by the hot air, hot water and steam systems.

Besides the lectures on Specifications, every other Thursday throughout both terms of the third year is occupied in working out a practical problem in construction and making the ordinary detail drawings for wood, stone, brick and iron work and the plans and elevations of a plumbing system. These drawings are made just as they would be in practice, and the experience the students gain from them is such that upon entering an office they are able

to make without much difficulty any ordinary detail. They are, therefore, able to begin as draughtsmen and not as students or office boys.

This course in Specifications sufficed to show how the various materials used in building are employed. It remained to organize a course upon the materials themselves. To be sure, lectures in hygiene, sanitary engineering, chemistry, physics, botany, and geology, had in earlier years supplied some of this information but it was not taken up from an architect's standpoint. For the last three years accordingly these lectures have been replaced by a course in Building Materials, and those on hygiene and sanitary engineering by the lectures on plumbing, heating, and ventilating already mentioned.

The lectures in Building Materials treat of the history, geology, botany, chemistry, physics, methods of manufacture, tests and uses of the materials mentioned in the specification, and they are illustrated by samples of lime, iron, clay, etc., in various stages of manufacture and also by models and diagrams of furnaces, kilns and processes of manufacture. These lectures like those in Specifications, are now given twice a week during the third year. They also are grouped under the head of Carpentry, Masonry, and Iron and Steel Work, and are so arranged that they accompany those in Specifications, subject by subject. When for example brickwork is taken up in the course in Specifications, the manufacture of bricks and the tests to be applied to them are explained in the lectures on Building Materials.

I. Under the head of Carpentry the various kinds of woods are treated; their botanical character, growth, preservation, decay, method of cutting and seasoning, the classification, grading and testing of lumber, and the manner of specifying the different grades. The structure of wood, the phenomena of shrinkage, the recognized defects in different kinds of timber and their various economic uses are also taken up. Finally a "key" is explained by which it is possible to identify with exactness the various species of wood. This key which is one of the publications of the United States Department of Agriculture, is based upon the invariable differences in the structure of the different woods. The usual botanical distinctions are useless for architects and engineers as they seldom see anything but the dressed lumber, stripped of its leaves, blossoms and bark. They need therefore to learn to

recognize lumber from its structure as shown on the different sections. To illustrate this, lantern slides of the cross sections highly magnified are thrown upon a screen and a set of Hough's Wood Sections of the Native American Woods, and samples brought from the lumber yards, are shown to the class. At the end of the lectures each student is provided with a sample of every kind of wood shown and is required to identify it, just as if it were a mineralogical specimen. This method of identification has now been tried long enough to show that the results are very satisfactory.

II. Under the head of Masonry come the soils, their bearing power, methods of determining it, etc.; then the building sands and limes, cements, mortars and concrete. In addition to the physics, chemistry and methods of manufacture, tests of the quality of limes and cements are performed before the class. The tests of cement are those recommended by the American Society of Civil Engineers and include tests for tensile strength, time of setting, hardness, soundness and fineness of grinding. Next winter it is proposed to make each student perform them himself in the laboratory of the Department of Mechanical Engineering, which is well supplied with the necessary apparatus. After this follow the various kinds of building stones, bricks and terra cotta. The methods of manufacturing bricks by the soft mud and stiff mud processes, etc., the advantages and disadvantages of each, and the tests to be applied, are also explained. Plaster and asphaltum complete the list of building materials mentioned in the masonry specification.

III. The materials treated under the head of Steel and Iron Work are cast iron, wrought iron and steel. The different ores used for their production, and the operation of a blast furnace are explained. Especial attention is given to the tests of the materials, the different methods of manufacture and the influence of these methods upon the character and quality of the product. The lectures furthermore include the operation of making castings, the contingencies which may arise in their manufacture and the tests to which all castings should be subjected; also the operation of rolling out the various wrought iron and steel sections.

Next winter it is proposed to organize a Saturday morning class for the inspection of buildings in process of erection and of various shops, such as rolling mills, brickyards, foundries, etc. This was

done several years ago but it had to be discontinued on account of press of other work.

A museum of building materials, appliances and models was started in a small way a few years ago and has already grown to considerable size. It contains a large number of models of wooden and steel construction, samples of bricks, terra cotta, stones, hardware and of nearly every other material mentioned in the specification. The specimens of terra cotta arches and fireproofing formed part of an exhibit at the Chicago World's Fair and were presented to the school by the exhibitors. The collection of native American woods is especially complete and includes all of the common species used in building and many of the rarer ones. The museum is not a mere haphazard and miscellaneous collection shut up in cases and useless for practical instruction, but a working laboratory, as all of the material in it is actually used in illustrating the lectures. A part of this equipment has been obtained by purchase, but the greater portion has been contributed by the generosity of manufacturers and dealers in this city.

The course in Architectural Practice is complementary to the course in Architectural Engineering and the two are so arranged that the same subjects are treated at the same time. Thus lectures in Architectural Engineering on the strength of rivets and the supporting power of columns, occur at the same time as the lectures in Architectural Practice on punching and drilling, the different methods of riveting and the various forms of built up columns. The practical work in both courses is also complementary; one Thursday for example, the problem will be the calculation for a riveted girder, and on the following Thursday the problem will be the making of a working drawing for the same girder. The practical work is moreover complementary to the Third Year Design; the problems in practice being made to cover some point in the construction of the problems in design. Thus among the design problems given out are the plans and elevations of a frame country house, a city house and some public building, such as a library, and the practical problems are, a framing plan and elevation of the country house, $\frac{1}{4}$ inch scale working drawings of the city house and the calculations for some of the arches, trusses or girders in the library.

The combined courses in Architectural Practice and Engineering cover the entire field of construction and may be taken inde-

pendently of the other work in the School of Architecture, by any one qualified to pursue them. Although they are intended primarily for students of architecture, parts of them at least might be taken with advantage by draughtsmen and superintendents in architects' offices, by builders, or indeed by anyone interested in building. Those who are properly qualified may enter the School as special students and select for study whatever subjects they care to. An article on "Professional Draughtsmen as Special Students in the School of Architecture," published originally in the QUARTERLY for July, 1897, has been reprinted for the School of Architecture, and copies of it may be obtained upon application to the school. It explains in detail the various courses open to special students and their standing in the school.

MASON 1.

NOTE. All of the general conditions prefacing this specification, except (§) apply to the execution of all works described under this heading.

PLATFORM AND BRIDGE PLATES 1 AND 2 M. *Before any work on the present site is begun*, the Contractor must erect *along the street front* a *yellow pine* platform and bridge, *ten* feet wide and *fourteen* feet high.

PLATFORM.
1
2 The uprights are to be 12″ x 12″, set *eight* feet on centres; the plates 12″ x 14″, and the sills (12″ x 12″) [6″ x 12″ securely bolted to both sides of uprights]; all are to be well bolted together and braced at all angles by 2″ x 6″ planks securely spiked.

The floor of the platform is to be made of 4″ x 12″ planks laid flatwise and well spiked to 10″ x 12″ cross timbers set *four* feet apart and well spiked to the plates.

BRIDGE.
2
1 The bridge * (under the platform) is to be made of 3″ x 12″ planks laid flatwise and well spiked to (6″ x 12″ sills) [to 6″ x 8″ cross timbers set *four* feet apart and spiked to sills] † (and provided with necessary supports properly braced); construct suitable steps at each end, and a strong handrail along the outside of steps and bridge, all to be well braced, bolted and fastened.

Over the bridge provide and put up a roof of 2″ x 9″ planks laid double with a 12″ pitch, and well

nailed to necessary supports * (spiked to uprights) † (properly braced.)

FENCE. Construct a fence *of spruce* 8–0″ high on the inside of (*platform*) [along the street front] with returns to building line, having all necessary posts and framework, and covered with ⅞″ *matched and beaded dressed boards* well nailed, and provide necessary doors and gates properly hung and fastened.

The fence is to be painted with two coats of white paint, and kept free from all signs and advertisements.

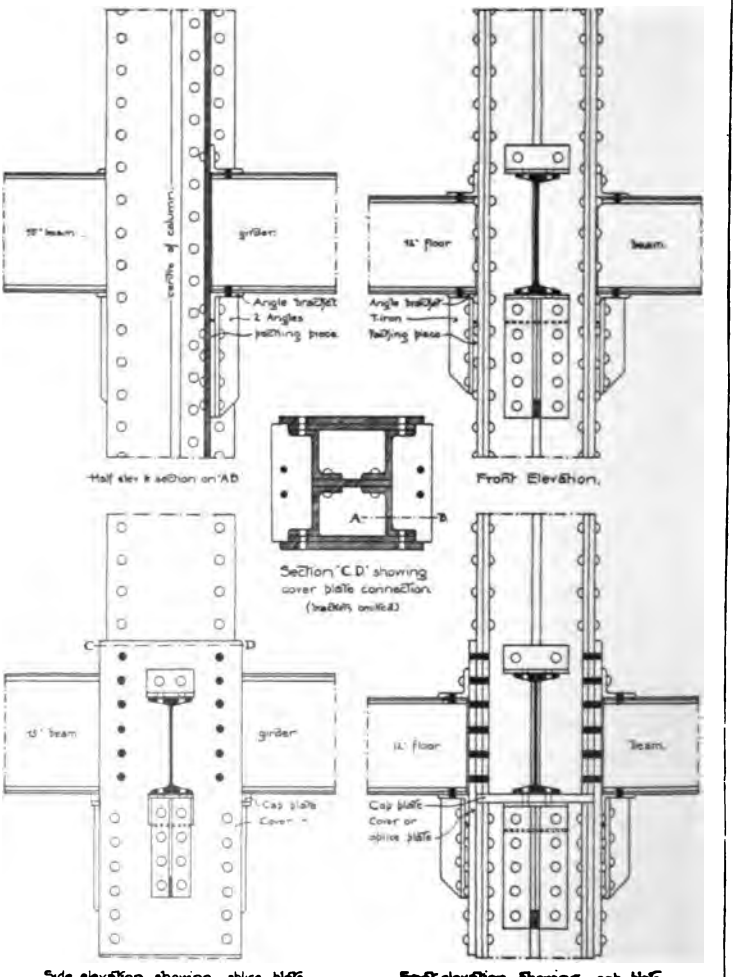
The bridge platform and fence are to be kept in thorough repair by the Contractor during the erection of the building; he must also make, at his own expense any alterations in the above.

* Insert when bridge is built under platform as shown in Plates 1 and 2.
† " " " " " without a platform.

PLATE 15,1.

Z-BAR COLUMN CONNECTIONS.

For specification see pages 9 and 10 I.



This column is two stories in height making the column joint at every other floor level. Plate 8,1. shows details of base connection.

Scale 1½"=1'-0"

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PLATE 14 C.

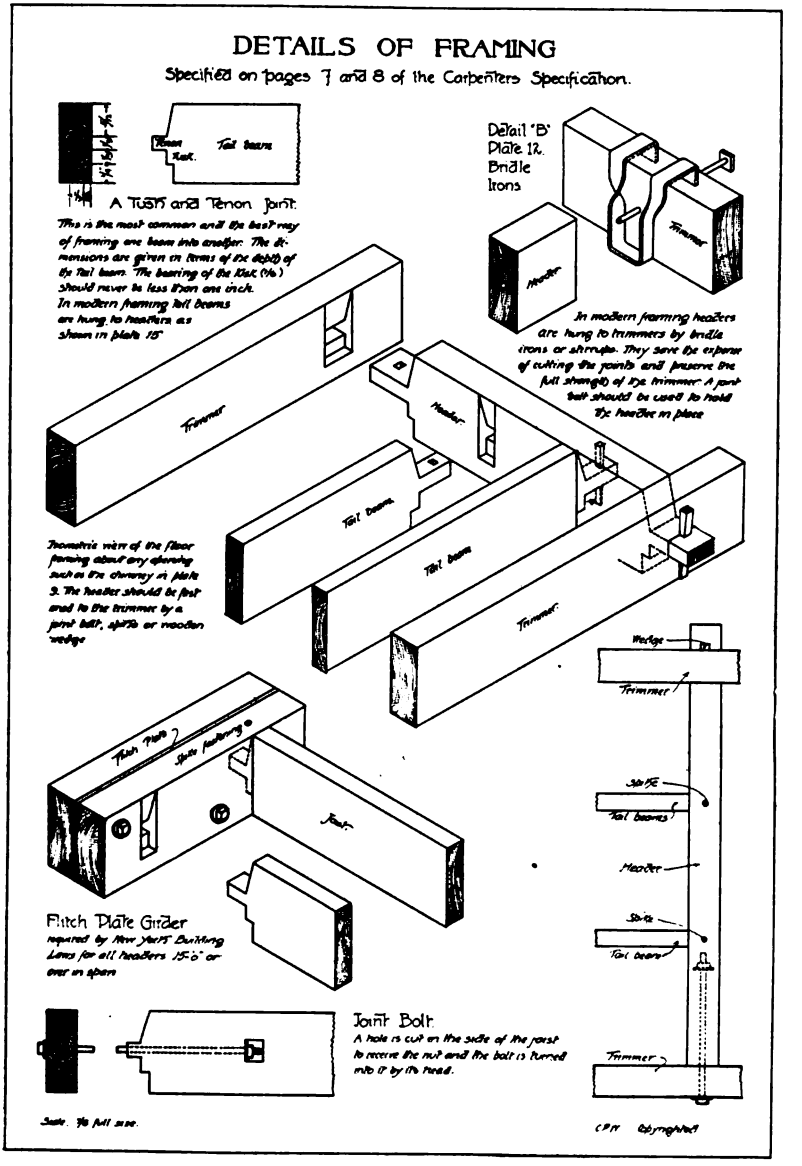

DETAILS OF FRAMING
Specified on pages 7 and 8 of the Carpenters Specification.
Tail beam
Trimmer
A Tusk and Tenon Joint.
This is the most common and the best way of framing one beam into another. The dimensions are given in terms of the depth of the Tail beam. The bearing of the Tusk (⅛) should never be less than one inch. In modern framing Tail beams are hung to headers as shown in plate 15.
Detail 'B' Plate 12. Bridle Irons
Header
Trimmer
In modern framing headers are hung to trimmers by bridle irons or stirrups. They save the expense of cutting the joints and preserve the full strength of the trimmer. A joint bolt should be used to hold the header in place
Isometric view of the floor framing about any opening such as the chimney in plate 9. The header should be first and to the trimmer by a joint bolt, spike or wooden wedge
Header
Tail beams
Trimmer
Wedge
Trimmer
Joist
Tail beams
Header
Skirt
Tail beam
Trimmer
Plan
Plate
Skirt
Joist
Flitch Plate Girder
required by New York Building Laws for all headers 15'-0" or over in span
Joint Bolt
A hole is cut in the side of the joist to receive the nut and the bolt is turned into it by its head.
Scale. ½ full size.

PLATE 35.

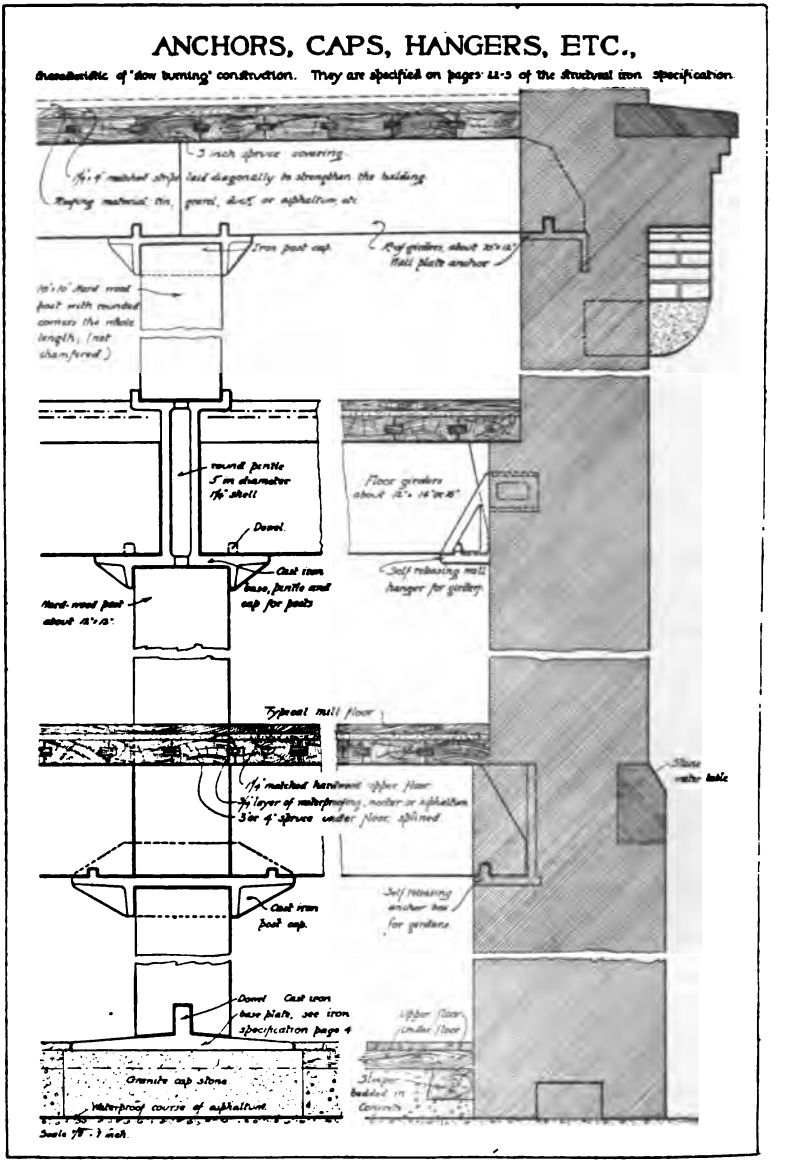
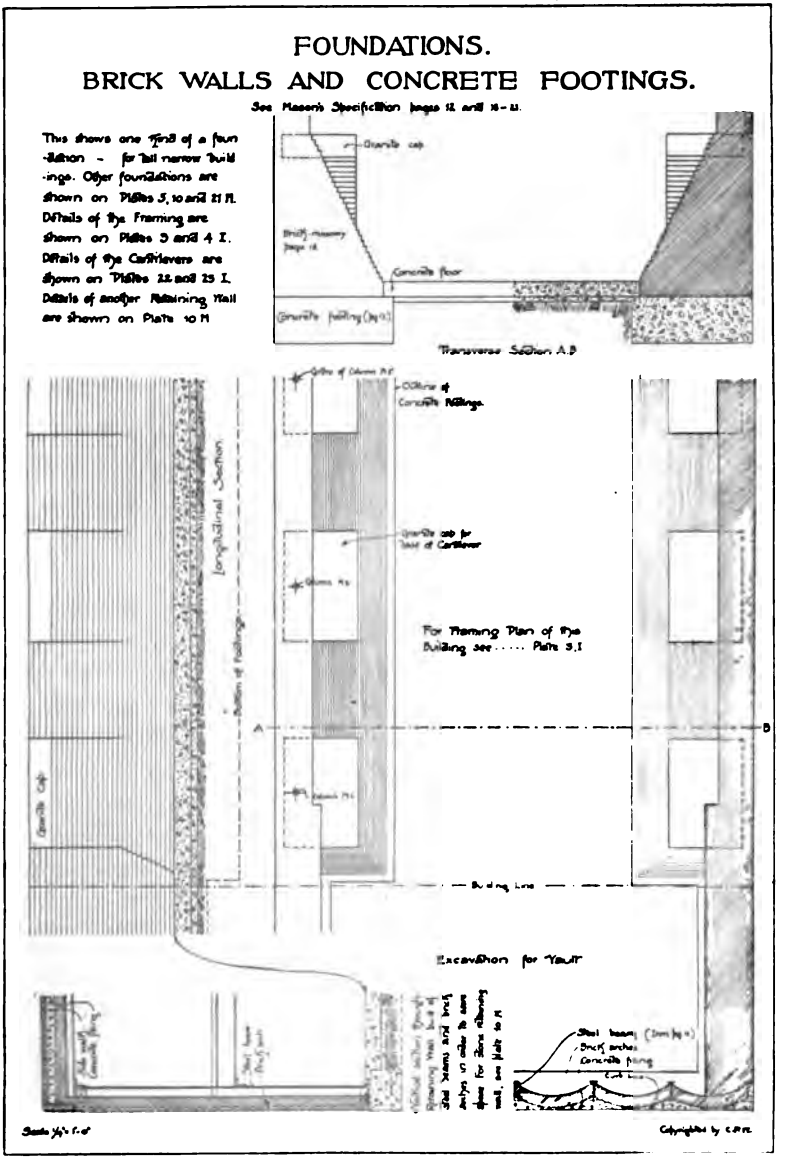

ANCHORS, CAPS, HANGERS, ETC.,
characteristic of 'slow burning' construction. They are specified on pages 11-3 of the structural iron specification.
3 inch spruce covering
1½" matched stripe
laid diagonally to strengthen the building
Roofing material: tin, gravel, slate or asphaltum etc.
Iron post cap.
Roof girders about 10"x 16"
Wall plate anchor
16"x 16" hard wood post with rounded corners the whole length. (not chamfered)
round pintle 5" in diameter 1½" shell
Dowel
Floor girders about 12"x 14" or 15"
Cast iron base, pintle and cap for posts
Self releasing wall hanger for girders
Hard wood post about 12"x 12"
Typical mill floor
1½" matched hardwood upper floor
½" layer of waterproofing, mortar or asphaltum
3 or 4" spruce under floor, splined
Stone water table
Self releasing anchor bar for girders
Cast iron post cap.
Dowel Cast iron base plate, see iron specification page 4
Upper floor
Under floor
Granite cap stone
Water-proof course of asphaltum
Sleeper bedded in Concrete
Scale ¾" = 1 inch.

PLATE 11M.

FOUNDATIONS.

BRICK WALLS AND CONCRETE FOOTINGS.


See Mason's Specification pages 12 and 16-17.
This shows one kind of a foundation - for tall narrow buildings. Other foundations are shown on Plates 5, 10 and 11 M.
Details of the Framing are shown on Plates 3 and 4 I.
Details of the Cantilevers are shown on Plates 22 and 23 I.
Details of another Retaining Wall are shown on Plate 10 M
Granite cap
Brick masonry
Concrete floor
Granite footing (3 ft 0)
Transverse Section A.B
Line of Concrete Footings
Granite cap for base of Cantilever
For Framing Plan of the Building see ..... Plate 3.I
Longitudinal Section
Bottom of Footings
Granite Cap
Building Line
Excavation for Vault
Steel beams (3 cm by 0)
Brick arches
Concrete filling
Scale 1/8" = 1'-0"
Copyrighted by C.M.R.

THE CONFLICT BETWEEN SIR ISAAC NEWTON AND THE FRENCH SCHOOL OF ASTRONOMERS CONCERNING THE FIGURE OF THE EARTH.*

By D. H. POLLARD.

The shape of the earth is a subject that has ever been of great interest to astronomers and philosophers. As far back as 570 B. C., we find them giving their views on this matter. At that time Anaximander believed that the earth was a cylinder whose height was three times the diameter of the base. Anaxagoras was of the same opinion. Plato in 400 B. C. also believed that he lived on a flat earth, only he supposed the surface was a square, and that the earth itself was a cube.

In 340 B. C. we have our first astronomer to advance the theory of the spherical form of the earth. This was Aristotle. He tells us that mathematicians had already computed the circumference, and found that it was 400,000 stadia. But Eratosthenes, nine years later, appears to have been the first to have an accurate idea of the correct principles on which the determination of the figure of the earth depends. He noticed that when the sun was exactly on the zenith at Syene, casting no shadow, at Alexandria at the same time it cast a shadow at an angle of $7^\circ\ 12'$ from the vertical. Then, knowing roughly the distance between the two places, he computed the length of a degree of the circumference of the earth, which he found to be 700 stadia. After Eratosthenes we have measurements made by others, of which we may mention those of Possidonius, who found the degree to be 666 stadia in length, and of Ptolemy, who obtained 500 stadia as a result.

Notwithstanding the correctness of the methods used by these early astronomers, the results they arrived at are of very little or no value to us, as it is not known how the stadium is related to the modern units of length. The first measurement of real importance and value was that of Fernel about 1500 A. D. He counted the number of revolutions of the wheel of his carriage as he traveled, selecting as his course a route following as closely as possible the direction of the meridian near Paris. Having in this way

* Graduation Thesis presented for the Degree of A.B, April 2, 1900.

found the distance between two places, he took the difference in latitude by astronomical observations, and then announced as the length of a degree 56,746 toises.

The next measurement of importance was that given in 1617 by Snell, a Holland astronomer. He took a long stride in the right direction by applying a triangulation instead of attempting to measure the linear distance. His observations and computations gave a result much smaller than that of Fernel, 55,021 toises, and this result was considered much more exact.

About twenty years later we have the first measurement given by an Englishman, that of Norwood. He found the difference in latitude of two places, by means of the sun's meridian altitude. Then, partly by measuring with chains and partly by pacing, he got the distance between two positions, from which he concluded that a degree was 367,176 feet or about 57,300 toises in length.

After this crude method of attacking the problem we have Picard's admirable plan. By the time that he started his work, in 1669, the telescope had been applied to circular instruments. Picard took advantage of this invention, and using great care and precaution, measured an arc of the meridian between Malvoisine and Sourdon, in France, by means of triangulation. His base lines were measured with rods, each two toises in length. His work furnishes us with the 57,060 toises as the length of the degree.

The observations just described were all made with a view of determining the size of the earth regarded as a sphere. It was not until some pendulum experiments, made by Richer, attracted attention that the possibility of the earth's having anything but a spherical form was conceived. Richer discovered that the pendulum of his clock, regulated to keep time at Paris, lost about two minutes and a half at Cayenne. His story was hardly believed until it was confirmed by similar disturbances in clock time noticed in Africa and America. The cause of this phenomenon was then sought. Newton was the first to give a satisfactory explanation, in the third part of his "Principia," which was published in 1687. Now some years previous to the publication of his "Principia" Newton had attempted to apply his law of gravitation in the determination of disturbances noticed in the action of the moon, but could never get results that agreed with observations made on the moon. However, when Picard announced his new measurement, Newton saw that he could now get satisfactory re-

sults from the application of his law of universal gravitation. So assuming this law, he said that the variation was either due to centrifugal force, which had a tendency to lessen gravity, or was caused by the fact that the earth was an oblate spheroid. Of these two explanations he probably favored the latter, because by considering the earth as oblate he was able to account for the precession of equinoxes; and also from his theory of gravitation he could see that a flattening of the earth at the poles would be caused. This theory concerning the shape of the earth was upheld by Huygens, in the treatise he published a few years after the "Principia," concerning the cause of gravity.

But in spite of the plausibility of Newton's theory, it was challenged almost as soon as it appeared. Between 1684 and 1718 Dominique Cassini and his son Jacques had extended the triangulation used by Picard and after having measured the length of a degree in both the northern and southern portions of the arc, found that the former gave 56,960 toises, and the latter 57,097 toises. For these results to be true the earth would have to be a prolate spheroid, instead of being oblate, as Newton and Huygens asserted.

Now, concerning the shape of the earth, there arose a dispute which was not settled until the French Academy sent out two expeditions, the one north, the other south, in 1735. There was not so much said on the side of Newton, but from the side of those who mainly upheld the Cassinian measurements and theory of the prolate form, there appeared many memoirs and papers to prove that the earth was prolate. And indeed the French had good reason for thinking that Newton was wrong, because his theory of gravitation had failed until he had used in his calculations Picard's measurements for a degree. Besides, Cassini had had better instruments and was much more careful in his work than Picard could have been, for which reasons his work should be more accurate.

David Gregory, the Savilian Professor of Astronomy at Oxford, was the first of any importance, after Huygens, to publish anything on the subject. In his "Astronomiæ Physicæ et Geometriæ Elementa," published in 1702, he upholds Newton not merely by agreeing that the earth might be an oblate spheroid, but by stating it as a positive fact. Also Hermann, a Dutch astronomer, in 1716 published a book in which the theories of Newton and Huygens

are maintained. For these views both men were later criticised by the French as having no foundation for their statements.

A short while before the appearance of this work of Hermann's, J. Cassini had published, in the Memoirs for 1713, an article maintaining the assertion that the earth is oblong, with its major axis passing through the poles. He mentions Newton's and Huygens' views to the contrary, and sets up against them the deductions drawn by Eisenschmidt. This astronomer had compared all the best measurements hitherto made, those of Snell, in Holland, Picard, in France, Riccioli, in Bologne, and Eratosthenes, between Alexandria and Syene. He found that the statistics showed that the further south the degree was measured the greater was its length. For this reason he reached the conclusion that the earth must be a prolate spheroid. As further proof Eisenschmidt cites Burnet, who, after a great deal of study, says that although the diurnal rotation of the earth tends to raise it at the equator, the resistance of the air has the opposite effect, and causes the particles to move towards the poles so as to maintain equilibrium, thus elongating the earth in the direction of the poles.

After giving Eisenschmidt's proof, Cassini compares his own recent observations with those of Picard. As his own measurements were exact and gave an increase in the length of degrees in going from north to south, he must believe in the prolateness of the earth's form. Moreover, his own results show that Picard did not get the exact difference between consecutive degrees. The difference is greater than Picard had announced, and the difference between the major axis and minor axis is even greater than had been supposed. Cassini found the greatest difference between consecutive degrees to be in the longitude of 45°, and the least at the poles or the equator.

Another well known member of the French Academy to take an active part in the discussion of the shape of the earth was Mairan. He placed implicit faith in Cassini's carefulness and accuracy, and then published, in the Memoirs of 1720, an article proving Cassini's views. His article contained dimensions worked out from Cassini's results as a basis; but far more interesting is his law to show that the force of gravity should decrease from the pole to the equator. First he said that the centrifugal force is greater at the equator than it is at the poles for a perfect sphere, for which reason the weight of a body is less at the equator. As

Newton's law did not show this for a prolate spheroid, Mairan invented a law of his own, which is as follows: At every point of the surface of a body of revolution the force of attraction would vary inversely as the product of the principal radii of curvature at that point." Assuming this law Mairan proceeds triumphantly to show that the force of gravity decreases in going from the pole to the equator in the case of a prolate spheroid, but increases if the spheroid is oblate. The Paris Academy accepted Mairan's opinions, so favorable to the cause, seemingly without question.

The next article of importance dealt directly with the papers of Mairan and Cassini. In 1726 there was published a "Dissertation Concerning the Figure of the Earth," by Desaguliers. Part of the work was devoted to the criticism of Cassini's measurements, but the more important portion opposed the view and law of Mairan. Of course, so far as criticising Mairan by asserting the trust of Newton's law was concerned nothing would come from it, as Mairan would simply refuse to accept Newton as an authority. But one thing that Desaguliers did do was to prove the inaccuracy of Mairan's law. He compared the results acquired by observing pendulum experiments with the results that should come about according to Mairan, and showed that, even if the theory of the prolate form of the earth were accepted as a fact, the pendulum would have to be shortened five times too much by following the law.

In addition to Desagulier's objections to Cassini appeared also a letter by Poleni, which Cassini thought worthy of response. Accordingly we have in the Memoirs of 1732 an answer to objections and criticisms that had been made. Cassini said that as he was one of the men referred to in Poleni's letter, he was bound to defend the accuracy of the work in which he was involvod. Then he replied to the objections in order. He asserted there could have been no error in the operations, as every precaution was taken, such as observing one star to verify the results given by observations made with another, and by reversing the apparatus used to secure accuracy. Then he dealt with the apparent proof of the oblateness of the earth derived from an eclipse of a satellite of Jupiter. Poleni said that such an eclipse had indicated that the earth is oblate. Cassini replied by asking if the astronomer who made the observation could be as nearly exact as four seconds, upon which exactness depended the truth of the proof. No

astronomers at that time thought they could be sure of the result within ten seconds. Other queries concerning the base line and triangles used by Cassini were answered, and as regarded the plan of measuring a degree of longitude, the reply was that such a scheme had been tried and tended to show that the earth was still more prolate than the measurements in latitude would indicate.

The next year after this response Cassini made some observations of his own in the length of a degree of longtitude, *i. e.*, east and west on the parallels of latitude, as compared with the length required for an earth which should be a perfect sphere. On the parallel passing through St. Malo he found the length of a degree to be 36,670 toises, whereas 37,707 toises were necessary for the condition that the earth should be a sphere. Also in the longitude of Strasburg the length of a degree was 37,066 toises, or 679 toises less than it should be for a spherical earth. These conditions being true, the only conclusion to be drawn was that the earth was not a sphere, but a prolate spheroid. Cassini de Thury was also making investigations as to the length of a degree of longitude with the result that he reached the same inference as J. Cassini. At Brest he found the degree too short by 300 toises, and at Nantes it lacked 781 toises of the required length. Therefore the Frenchmen thought there should be no reasonable doubt concerning the prolate form of the earth, and in the article that J. Cassini published upon the investigations we have the following conclusion: "We remarked in the preceding memoirs that supposing the earth to be of an elliptical form, with the major axis passing through the poles, as results from observations on the meridian, the degrees of longitude should be less than if the earth were spherical. Thus all the observations made from the south to the north, from the east to the west, agree in giving the earth the form of an ellipse elongated towards the poles, which fact, if not regarded as complete proof, ought at least to be a great argument in favor of this opinion."

During the same year that Cassini was measuring his degree of longitude appeared an article by Maupertuis. This gentleman gives an impartial review of the different theories held by both schools, and of criticisms made by the one against the other. However, he himself does not uphold either school, although in the solutions of his problems he uses illustrations which show plainly his leaning towards the Cassinian theory.

The next year, 1734, John Bernouilli, in competing for a prize offered by the French Academy, devoted part of his essay to the consideration of the shape of the earth. In this he was unfair, possibly because he disliked Newton, or because he wished to support his own countrymen. He assumed the old Cartesian theory, depending upon the principle of vortices, and then proved that the earth must be prolate. It is rather a strange circumstance that about sixty-five years before, in 1669, Huygens read a paper before the French Academy, in which he said that theoretically, the centrifugal forces of Descartes would necessarily lead to the conclusion that the earth would have a flattening at the poles. Thus we have opposite results from the same hypothesis.

For the year 1735 we have two articles worth consideration, one by Maupertuis, the other by Stirling. This time Maupertuis argued directly in favor of Cassini. He said that Newton's theory, upheld by Gregory, needed proof, because observations tended to disprove its truth. He then showed that Cassini's measurements could have an error of ninety toises without disproving the theory that the earth's form is elongated towards the poles. The article by Stirling took the opposite view. He computed the diminution in the force of gravity, and found that four-fifths of it is due to centrifugal force. Then Stirling asserted that "as the earth could not be oblate unless it revolved, nor could it revolve without assuming that shape, the diminution of gravity from the poles to the equator proves both rotation and the fact that the earth is an oblate spheroid." Owing to the conflict between this theory and the observations of the length of a degree, he pronounced himself not entirely satisfied, but he hoped for a definite decision after the French expeditions made their measurements.

The expeditions mentioned by Stirling were two sent out in 1735. The conflict about the shape of the earth had caused a split in the Academy, some favoring one view, others the other. Some had maintained the view of Huygens until Eisenschmidt's essay reached them, when they turned to his way of thinking. The larger number favored the prolate form, but the feeling was so strong that finally the king ordered two expeditions, under expert astronomers, to be sent out; one to go to the north the other to the south. In this way he hoped to settle the question once for all.

Accordingly the expeditions were quickly prepared. The one

to go to the north was composed of Maupertuis, Clairaut, Camus, Le Monnier, the Abbé Outhier, and Celsius, the professor of astronomy at Upsal. Those to make the expedition south were Godin, Bouguer and de la Condamine.

The expedition to the north was the first to complete its work, the men arriving home about sixteen months after their departure. The degree measured at Tornea by them was 377 toises longer than the mean degree in France, and 900 toises longer than the degree should be as computed according to Cassini's hypothesis. Then Cassini raised the objection that the result could not be depended upon, because there was neither a double observation, nor a reversal of instruments for verification. Maupertuis answered by saying that Picard did not take the precaution required by Cassini, and that anyway the instruments used in the last expedition were of such a quality that it was not necessary to take so much trouble. Then in turn Professor Celsius questioned the accuracy of Cassini's computations, and showed a method devised by a friend, Olaus Hiorten, which gets a smaller result from Cassini's triangles, and proves the earth to be oblate. Celsius said he did not believe that the observations taken in France had the degree of exactness sufficient to be depended upon in a question of fifty years' dispute.

The expedition sent to the south had a much harder time and about ten years had elapsed before the astronomers returned home. But when their results were compared with those of Maupertuis and his co-workers, it was found that the degree in Peru was much less than that at the north. For this reason they were compelled to admit that the earth is an oblate spheroid, and that Newton was correct in his theory.

New measurements were made of the old arc in France by Cassini de Thury, in 1740. He divided the arc into parts and found that the degree in the northern part was the greater. This measurement was the basis of a claim that he and his party were the first to settle definitely the question as to the shape of the earth. But this is not just. Both the northern and southern expeditions had more right to make such a claim, and indeed each of them did make it. Works were published individually in which some of the men seemed to take all the credit upon themselves.

BIBLIOGRAPHY.

BAILLY, T. S.—Histoire de l'Astronomie, Ancienne et Moderne.

DELAMBRE.—Histoire de l'Astronomie an XVIII^me. Siècle.
GRANT, R.—History of Physical Astronomy.
HISTOIRE DE L'ACADÉMIE DES SCIENCES. Volumes for 1713, 1718, 1720, 1732, 1733, 1735, 1737, 1742.
MONTHLY NOTICES OF ROYAL ASTRONOMICAL SOCIETY, Vol. XIV.
ROYAL SOCIETY OF LONDON, Philosophical Transaction, Volumes XXXIX and XLI.
TODHUNTER, L.—History of Theories of the Figure of the Earth.
WALLER.—The Measure of the Earth.
SMITH, W.—Greek and Roman Biography and Mythology.
ENCYCLOPEDIA BRITANNICA, "Earth, Figure of."
CLARKE, A. R.—Geodesy.

(Contributions from the Havemeyer Laboratories of Columbia University, No. 26.)

ON THE PRODUCTION OF ASYMMETRICAL ALTERNATING CURRENTS BY MEANS OF ELECTROLYTIC POLARIZATION.*

BY WALTER LEO HILDBURGH, E.E., A.M.

INTRODUCTORY.

Although many asymmetrical conductors are known, none at present seem so well adapted to the purposes of scientific research and practical engineering as those operating electrolytically. No homogeneous asymmetrical conducting material has been found. The following paper deals only with asymmetrical conductors whose action depends on counter E. M. F.'s produced by electrolysis, of which the two-cell rectifiers were previously known, the single-cell rectifiers being original with the writer. The action in aluminum and similar cells, generally supposed to be due to the production of resistant films, is not considered. The lack of previous work on the subject and the large field to be covered have made it necessary to touch only on what have seemed the more important points, and to treat even those in a preliminary rather than a final manner.

About half of the current curves of rectifiers in operation were read and plotted by Messrs. R. E. Slaven and H. K. McIntyre, to whom the writer's thanks are due for their earnest coöperation

* Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the Faculty of Applied Sciences, Columbia University, 1900.

with him; the remainder were taken by the author. Approximately 160 curves were read, about three-fourths of which have been utilized. The present opportunity is taken to acknowledge indebtedness to Professor M. I. Pupin and Dr. J. L. R. Morgan, in whose laboratories the work was carried on, for their interest and suggestions, and to the Crocker-Wheeler Electric Co., and the Electrical Engineering Department of Columbia University for apparatus loaned for the investigation.

The following terms are proposed, and will be employed throughout the paper:

The *asymmetrical efficiency* of a rectifier is the ratio of total to useful unidirectional current in an asymmetrical current conductor.

A *two-cell rectifier* is an asymmetrical conductor, including one or several similar parts, each of whose parts consists essentially of two electrolytic elements.

A *single-cell rectifier* is an asymmetrical conductor each of whose similar parts consists essentially of a single electrolytic element.

An asymmetrically affected alternating current is one whose first and second half waves represent different quantities of electricity.

The "*Useful*" part of an asymmetrically affected alternating current wave is the larger part. The "*Useful*" current flows during the time represented by that part of the wave, and in the "*Useful*" direction.

The "*Useless*" part is the smaller part of the wave, and neutralizes a portion of the work of the "*Useful*."

APPARATUS.

The experimental work was of two kinds: Preliminary, to determine whether a conductor would act asymmetrically, and its general mode of operation; and curve-tracing. In the preliminary experiments, the cell to be tested was placed in a circuit with the source of E. M. F., a rheostat, and an ammeter of about 113 ohms resistance (testing coil of a 600-v voltmeter). Direct E. M. F. was obtained from gravity cells; alternating by passing the direct through a two-part commutator, with collecting rings, on the shaft of a motor of adjustable speed. Current for the curve-tracing was supplied by a small bi-polar converter, the voltage desired being taken from a slide-wire in series with lamps or self-induction, according to whether the upper harmonics (third and fifth) were or

were not wanted. The frequency was maintained constant by means of a rheostat in the motor armature circuit. Readings were taken generally 10° apart; smaller divisions down to ½° were made when necessary. The regular width of the contact point was about ½°, though for the lower readings a considerably greater width was found essential. Temperature changes in the cells tested, during a set of readings, were inappreciable, due to the relatively large masses of liquid employed.

The ordinary Mershon method of obtaining readings was used with such refinements as were required. The telephone was of German manufacture and extremely sensitive, being adopted after a trial of an ordinary receiver, an optical telephone, a telephone with microphonic contacts in the circuit of a second receiver, a Lippman electrometer, and a tangent, a D'Arsonval, and a Thompson galvanometer. The measuring circuit was thoroughly insulated and separated from the frame of the machine, avoiding leakage currents at speeds higher than those used. The apparatus, as used, was capable of balancing and reading to within about .001 volts, representing approximately .00001 ampéres though the voltmeter (testing coil of 600-V voltmeter).

Curves were checked by repeating a number of readings selected at random. A slow change in the cells, due, probably, to some action at the electrode surface, was found to occur even in the "single-cell" curves, in which all precautions to attain accuracy and constancy were observed. In some cases it was necessary to pass current for an hour before recording values; the effect was very slight under ordinary circumstances, but became especially marked at the higher voltages and when inductance was present, making the taking of certain curves a practical impossibility. Changes in the electrode surface due to use introduce an element of uncertainty, so that it becomes necessary to regard even the set of related curves given in a qualitative rather than a quantitative way. The curves illustrated are plotted to several different scales, as should be noted in comparing them.

Small electrodes were made by sealing platinum wire into glass tubing, filing to a plane surface, and burnishing; larger ones by leaving a projecting end, to which, for still larger electrodes, a sheet of foil was welded. Platinizing was done in a solution of platinic chloride to which a little lead acetate had been added. Palladium black was deposited from the pure chloride, with a palladium anode.

I. The Two-cell Rectifier.

The two-cell rectifier appears to have been the earliest asymmetrical conductor operating, by the electrolytic production of counter E. M. F.'s, in a manner to warrant its introduction into practice. The theory of its action is simple, and forms readily a basis for the discussion of the theories of other types. The device consists of the combination in series of an active cell *A.* (Fig. 1) and a pas-

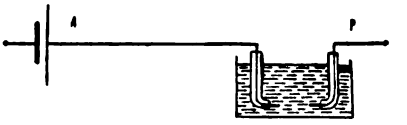


Fig. 1.

sive or polarization cell *P.* A is any cell which will produce a current when applied to the terminal of a circuit; *P* a cell incapable of producing a current of itself, but which will give a counter E. M. F. when an active E. M. F. is applied to it in either direction. The active and passive E. M. F.'s are preferably balanced by making the active E. M. F. just less than the counter E. M. F. of the passive cell at the decomposition value, so that no current can flow on closed circuit without the application of an external source of E. M. F. A Daniell cell and a cell having water between platinized electrodes, for example, might be used.

Operation with Direct Currents.—If a direct E. M. F. be applied to the combination just described in a direction such that it aids the E. M. F. of the active cell, a direct current will flow as if neither active nor passive cell, neglecting their ohmic resistance, were present. If, however, the impressed E. M. F. be opposed to the active E. M. F. and less than the sum of the active and passive E. M. F.'s, equal to twice the active E. M. F., no continuous current can flow; when the impressed E. M. F. is great enough to cause a flow of current that flow is produced by an E. M. F. equal to the difference between the impressed and twice the active E. M. F. Since in the opposite direction the effective E. M. F. is always equal to the impressed, an E. M. F. periodically changing in direction will cause more current to pass in one direction than in the opposite direction, the best effect being produced when the impressed E. M. F. is not greater than the sum of the active and passive E. M. F.'s. That is, a rectification of an alternating current will be produced.

Action of Passive Cell.—The electrodes in a polarization cell form an electrolytic condenser and will act, until the decomposition value is reached, like an electrostatic condenser of the same capacity, in series with a resistance equal to that of the cell, would act. The function which the condenser current plays in a two-cell rectifier was first recognized, so far as the writer knows, by Prof. M. I. Pupin. In 1894 he constructed, by using sufficiently small plates, efficient two cell rectifiers operating at high frequencies. An electrolytic condenser differs from an electrostatic mainly in that its counter E. M. F., increasing with the impressed E. M. F. more or less uniformly up to a certain voltage (the decomposition value), then increases in a very much smaller, and decreasing, ratio, so that after the polarization reaches the decomposition value the cell discontinues its condenser action almost entirely and acts as a simple ohmic resistance in series with a counter E. M. F. As long as the polarization E. M. F. in the passive cell, due to the current through a two-cell rectifier, remains below the decomposition value the passive cell acts as a condenser. But when the decomposition value is reached the passive cell acts as an ohmic resistance with but little capacity in series with an E. M. F., by construction equal and opposed to the E. M. F. of the active cell.

Consequently, assuming that there is cessation of the condenser action at the decomposition value, the curve of a current produced by an alternating E. M. F. acting on a two-cell rectifier will be composed of two parts; one in which a current flows due to the impressed E. M. F. acting through a capacity and a resistance in series, the other in which a current flows due to the impressed E. M. F. acting through an ohmic resistance alone. The shape of this curve, as shown by experiment and deduction, is largely dependent on the size of the passive plates and the relation of their capacity to the other constants of the circuit.

In the following deductions the action of the electrolytic condenser, has, for simplicity, been assumed to be perfect. That is, it is supposed that no continuous current can flow before the decomposition value is reached, and that the polarization E. M. F. below the decomposition value is proportional to the integral current between the plates, and above that value is constant. Except within certain limits no one of these assumptions is correct, but undue complication is thus avoided, and only minor modifications of the main theory necessitated. In the two-cell rectifier a small

continuous current flows, due probably to the oxidizing power of the liquid and diffusion; the capacity of the plate is variable; the increase of the polarization of the plates does not abruptly cease at the decomposition value, but may bring the polarization far above 1.67 volts (the generally accepted value for burnished platinum in dilute sulphuric acid) under certain conditions; and only a part of the electrical energy passing through the circuit charges the condenser, the remainder being lost as heat within and without the rectifier. The capacity of an electrolytic condenser, per unit of area, is far greater than that of an electrostatic.*

Operation with Alternating Currents.—If the first half-wave of current sent through the theoretical pair of cells forming the rectifier be produced by an E. M. F. in the same direction as the active its shape will be the same as that of the impressed E. M. F. If, however, the first half-wave of E. M. F. be in the direction opposite to that of the active the charged electrolytic condenser will be discharged to a degree dependent on the time and rate of flow of the current. The curve of discharge of a condenser (held charged by an active E. M. F.) by an alternating current suddenly impressed upon its circuit is the same as its curve of charge from an uncharged state, other conditions being the same, and depends not only on the constants of the circuit—the resistance, capacity, self-induction, and the frequency of the impressed E. M. F.—but also on the value of the current which would be flowing after a state of rest had been attained at an instant corresponding to the instant of closing the circuit. It is the algebraic sum of the curve of current which would ordinarily flow and a logarithmic curve whose values are dependent on the strength which that current would have at the instant of "make."† The inductance, in the following, is assumed to be zero; its presence causes complications which will be described later.

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* Polarization by Alternating Currents: Wien; *Wied. Ann.* 58, No. 1, p. 37. Also for change of capacity with frequency.

Polarization Capacity of Reversible Electrodes: Neumann; *Wied. Ann.* 67, No. 3.

Polarization Capacity of Electrodes: Gordon; *Wied. Ann.* 61, No. 1, p. 1.

Cathodic Polarization: Roszkowski; *Zeit. für Phys. Chemie*, Vol. XV., 1894, p. 267.

Cathodic Polarization: Caspari; *Zeit. für Phys. Chemie*, Vol. XXX., 1899, p. 89.

Anodic Polarization: Glaser; *Zeit. für Electrochemie*, Vol. IV., p. 376 Feb. 20, 1898.

† Bedell and Crehore: "Alternating Currents."

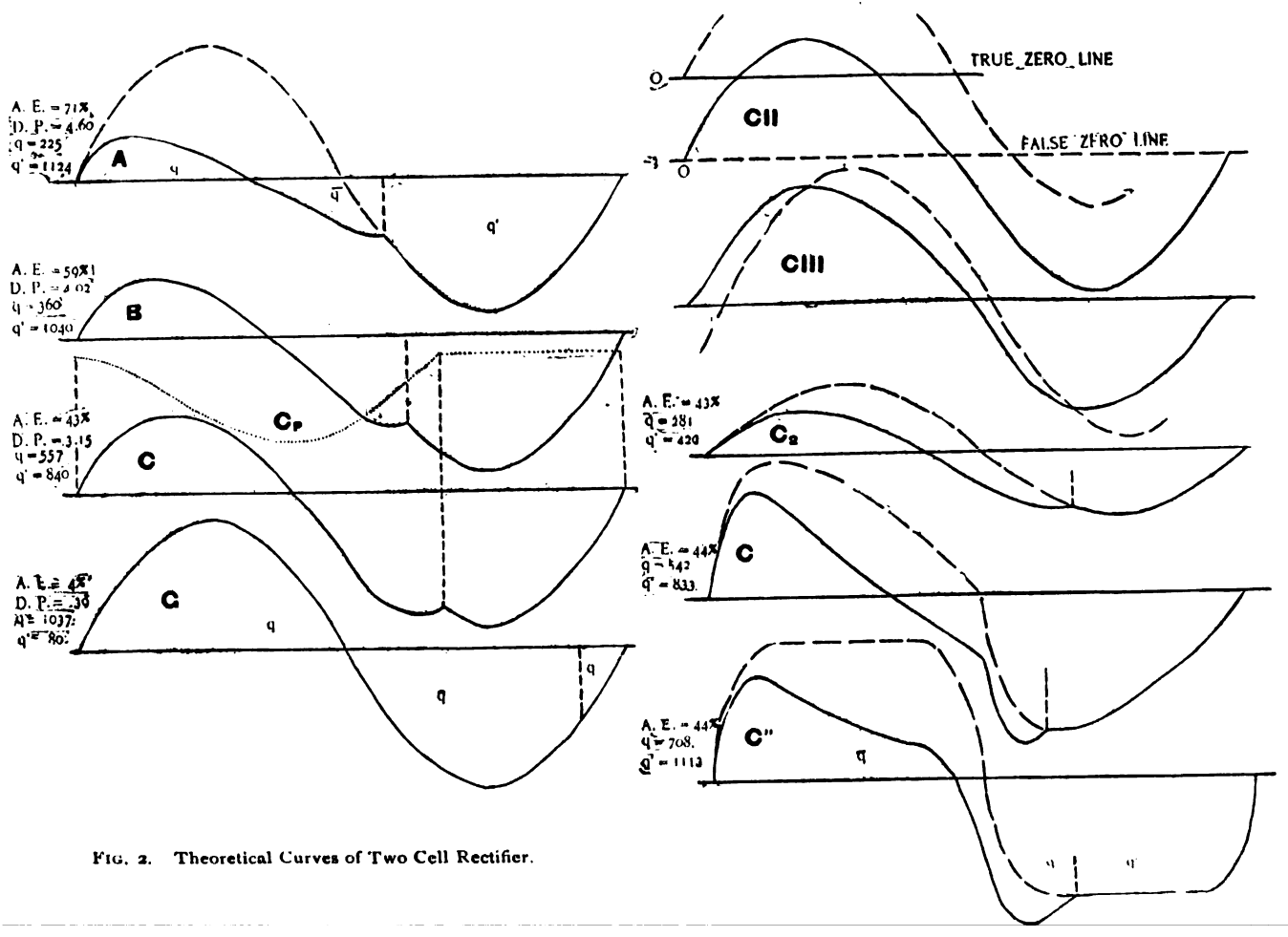

FIG. 2. Theoretical Curves of Two Cell Rectifier.

The second part of the curve, being that of a current through a resistance only, will have the same form and the same zero-point as the impressed E. M. F., the condenser remaining charged to the same potential throughout. The current curve is thus divided into a number of similar parts, each being of the same length, and having the same alternate zero-points, as a complete E. M. F. period. If, however, the active E. M. F. be too low a lead is produced; if too high, an apparent lag. An increase in the polarization after passing the decomposition value also has a tendency to increase the lead. The complete curve may be separated into three divisions (see Fig. 2); one in which the condenser is discharging, and one in which it is recharging, and one in which it remains fully charged and has no effect on the shape of the curve. The areas of the first and second of these divisions are evidently equal (assuming that no loss of energy occurs in the circuit during the charging and discharging of the condenser), representing equal quantities of electricity taken up and given out by the condenser, and are the areas of the "useless"* part of the curve and the first part of the "useful." Calling the area representing this quantity of electricity q, and the remainder of the "useful" q', the total quantity of useful current in each period is $(q' + q - q) = q'$, the total current of all kinds is $(q' + q + q) = (q' + 2q)$, and the ratio between those quantities, equal to $\frac{q'}{q' + 2q}$, and termed the asymmetrical efficiency, is the efficiency of transformation.

The effect of the frictional loss in the circuit is to make the amount q of the "useful" less than the "useless" by a quantity representing the amount of that loss.

Theoretical Curves.—For the determination of the theoretical curves *A* to *G* (Fig. 2), a method of approximation based on the division of a period into a number of very small parts, in each of which the action is uniform and in accordance with the foregoing theory, has been employed. The results in each case can be shown to closely approximate the true form of the perfect curve. The broken line in *A* shows the form of the E. M. F assumed; the curves *A*, *B*, *C* and *G*, illustrate the effect of increasing either the area of the plates, the resistance of the circuit, or the frequency, each alphabetical step (*A*—*B*; *C*—*D*) representing a doubling of

* See "Introductory."

one of those quantities. The figures at the left of the curves give the areas of q and q', the asymmetrical efficiency, and the maximum decrease in polarization (D. P) from the assumed original polarization of 5.00 volts. For D (not shown) $q = 762$, $q' = 542$, A. E. = 26%, D. P. = 2.13; for E (not shown) $q = 926$, $q' = 411$, A. E. = 18%, D. P. = 1.30. The dotted curve C_p represents the polarization of the passive plates in C. Curves C II and C III show respectively the effect of increasing and decreasing the active E. M. F. with respect to the passive, the conditions of area of plates, frequency, and resistance being the same as in C. C_2 shows the effect of halving the impressed E. M. F. C' and C'' show the effect of E. M. F.'s not sine curves. In all the balanced "C" curves the asymmetrical efficiency is about 43%.

Effects in Rectifiers in Operation.—The foregoing having been proven by work on rectifiers in operation to be substantially correct, has been used to explain the experimental data presented elsewhere in the paper. Very few of the deductions are unverified by direct experiment. The results are as follows:

The angle of lead produced by a condenser of capacity C in a circuit whose resistance is R, when the angular velocity of the impressed E. M. F. is p, is $\varphi = \tan^{-1}\frac{1}{pCR}$. The greater this lead the higher will be the current value when the impressed E. M. F. is zero, and the greater, consequently will be the logarithmic curve previously mentioned, and the smaller will be the "useless" half-wave. When φ is a maximum, 90°, the "useless" disappears, making the rectified current of the form of an E. M. F. half-wave, and the asymmetrical efficiency 100%. It follows that the efficiency becomes greater the smaller the resistance, the frequency, or the area of the plates, and is a maximum only when one of those quantities is infinitely small. In general anything which increases φ increases the efficiency.

Resistance.—It can be shown that in a circuit containing a perfect electrolytic condenser in which all the electrolyte is in a prism between plates at a fixed distance apart, and a negligibly low external resistance, the angle of lead is constant, no matter what the size of the plates. Similarly, in a rectifier in which the resistance external to the passive cell is negligible the efficiency depends only on the frequency and the distance between the plates. In a two-cell rectifier the larger the external resistance the less

will the efficiency be changed by a certain proportionate change in the size of the plates; when the external resistance is infinite no change is produced, the efficiency being zero. There is a series of maximum values of the efficiency, one for each frequency, in any particular rectifier, which are reached only when there is no external resistance. The plates of a rectifier should be as close together as possible, thus increasing the efficiency and decreasing the heat (C^2R) loss.

Frequency.—The higher the frequency the lower will be the efficiency; in any rectifier having plates of finite size the efficiency can be 1 only when the frequency is zero, that is, with direct current. When the frequency is very high, in a theoretically perfect rectifier, but little effect is produced; in practice the effect is increased due to the capacity of the passive plates becoming smaller as the frequency rises. No matter what the frequency or the size of the plates a perfect rectifier produces some rectification; in simple alternating current electrolysis, on the contrary, there is a limiting frequency, keeping other conditions constant, above which, visible decomposition will not occur.

Polarization of Plates.—The effect, on the curve representing the polarization of the passive plates, of changing the size of the plates (or the external resistance or the frequency, other conditions remaining constant) is as follows: Before impressing an alternating E. M. F. on the rectifier, the polarization curve is a straight line parallel to the zero-line at a distance equal to that of the active E. M. F. When the plates are very large an alternating E. M. F. starts a decrease in the polarization, at the beginning of each period, which lasts until nearly the end of the period. As the plates become smaller the change lasts a shorter and shorter time until finally, when they are infinitely small it lasts a half-period, the polarization following the E. M. F. (active and impressed) exactly, but in the opposite direction. When the plates are finite, but exceedingly small, the "useless" passes during a little over ¼ period, and the first part of the "useful" for about ¼ period; for maximum rectification the "useless" passes for 90° and the "useful" passes for 270°. The dotted curve C_p (Fig. 2) is that of the polarization when C is the current curve.

Impressed E. M. F.—In a perfect rectifier the quantities q and q' will be proportional to the impressed E. M. F., provided that the passive plates are not overcharged in the "useless" direction; the

unidirectional current, q' as read by an ammeter, will therefore be proportional to the impressed voltage. The efficiency is independent of the shape of the impressed E. M. F. wave. If gas bubbles are produced by the "useless" current the efficiency is decreased, since beyond the decomposition value the counter E. M. F. is not increased by the "useless" flow, and ammeter readings are no longer proportional to the impressed E. M. F. The larger the plates, or the greater the external resistance, or the higher the frequency, as in the analogous case of an electrolytic condenser, the higher may be the impressed E. M. F. without disturbing the proportionality of the current to it, although the "direct" current, q', for any particular E. M. F. is decreased. Consequently, the larger the plates or the higher the frequency the higher the ammeter reading obtainable. For infinitely small plates the maximum value of the impressed E. M. F. must not exceed twice the active E. M. F., equal to the sum of the active E. M. F. and the decomposition value of the electrolyte.

Decomposition Value.—The higher the decomposition value the higher may be the impressed E. M. F. per rectifier, other conditions being the same. If the decomposition value be not overstepped in the "useless" direction, it has no effect on the efficiency. The reaching of the decomposition value by the current produced by a given impressed E. M. F. of a certain frequency is a limiting factor in determining the inferior limit of the size of the plates (or of the capacity), and consequently the superior limit of the efficiency; this, naturally, need be considered only when the maximum of the impressed E. M. F. is more than twice the active.

The maximum potential difference attainable at either passive plate and the relation of those differences to each other, have no effect on the efficiency; when all + ions are gone from one plate there may still be — ions on the other, or ions of the same polarity may be on both plates simultaneously.

Active E. M. F.—If the active E. M. F. in a balanced rectifier be increased the zero-line of asymmetry (the line representing the continuons current before the alternating E. M. F. is impressed) will be shifted (C II, Fig. 2), and only the part of the "useless" projecting above the true zero-line will be choked, thus reducing the efficiency, though the amount of unidirectional current is increased. If the amplitude of the impressed E. M. F. be less than the distance between the true and false zero-lines asymmetry will

cease. The efficiency increases with the impressed E. M. F. until the decomposition value is reached by the "useless" current, after which the efficiency decreases. The current in an "overbalanced" cell is not proportional to the E. M. F., except at certain voltages.

If the active E. M. F. be decreased the capacity effect becomes more marked, reducing the efficiency; when the active E. M. F. is zero the efficiency is zero. This fact prevents the use of the rectifier in circuits in which the work done is against any considerable counter E. M. F. If the impressed E. M. F. is too low to cause the decomposition value to be reached in the "useful" direction no asymmetrical effect will be produced. The higher the impressed E. M. F., up to the point at which the decomposition value is reached on the "useless" side, the higher will be the efficiency; above that point the efficiency decreases. A lead is produced by "underbalancing," which becomes less the higher the impressed E. M. F.

Increasing Size of One Plate.—The capacity of an electrolytic condenser whose plates have capacities C_1 and C_2 is $\frac{1}{\frac{1}{C_1}+\frac{1}{C_2}}$. If one plate in a two-cell rectifier could be made actually infinite in capacity, and the active and passive E. M. F.'s were balanced, it would disappear from consideration. It would be immaterial, so far as the efficiency was concerned, whether the large plate were connected to the positive or negative plate of the active cell, the same number of ionic charges being needed to change the small plate from maximum oxygen polarization, for example, to maximum hydrogen polarization as to change it in the reverse direction, the maximum polarization in each case marking the end of the condenser action. The theory of the single-cell rectifier will be shown to be exactly the same as that of this type.

It is clear that while an inert electrode cannot be made really infinite in area it can be made so large that small quantities of current will not appreciably change its polarization. The rectification will then be accomplished entirely by the smaller plate, but the large plate will not be inactive, becoming gradually covered with gas, giving a counter E. M. F. Since this counter E. M. F. is dependent on the gas deposited, consequently on the respective polarities of the active and passive cells, a higher efficiency is ob-

tained by connecting the larger plate in dilute H_2SO_4, to the negative pole of the active cell than to the positive pole. When the larger plate is connected to the positive pole anything which decreases its maximum polarizability, as platinizing, increases the efficiency. In practice the action is complicated by phenomena occurring during the decomposition of dilute H_2SO_4 between electrodes differing greatly in size.*

Imperfect Action.—The gases produced at the passive electrodes should be freely and instantly discharged, storage of material at either electrode being detrimental to the efficiency. The electrolyte should be free from all traces of a salt of a metal not readily oxidizable and which may be deposited. The electrolyte should be such as to give the plates the smallest capacity per unit of area compatible with low internal resistance.

An electrostatic condenser cannot be used in place of the electrolytic; its attainable charge is limited only by the voltage, it can never act as an ohmic resistance without capacity, and it is not irreversible. Rectification cannot take place in a circuit containing an electrostatic condenser in series.

Efficiency.—The *commercial efficiency* of any rectifier is the product of the *asymmetrical efficiency* and the ratio of the work plus losses in the external circuit and the losses in the rectifier. In the two-cell rectifier the commercial efficiency is 100% only when the current is direct and the internal resistance negligible. The greater the external resistance the lower will be the asymmetrical efficiency, and the higher the ratio between external work and internal losses. There is, consequently, for each frequency, a particular size of plates when the external resistance is kept constant, or a particular external resistance when the size of the plates is kept constant, at which the commercial efficiency is a maximum.

Wasting of Active Cell.—The active cell in a balanced rectifier is wasted by doing a certain part of the work in the circuit, equal in amount to the energy contained in the bubbles from the passive plates. The lower the impressed E. M. F. the smaller the proportion of the total work in the circuit done by its source. For almost maximum asymmetrical efficiency the impressed E. M. F. is of very low frequency, and the work done by it is just over $\frac{2}{3}$ of the total, the cell doing $\frac{1}{3}$. The higher the frequency the higher may be the proportion done by the impressed E. M. F.

* See "Continuous-Acting Rectifiers," Part II.

Rectifiers for High E. M. F.'s.—Rectifiers for high voltages may be formed by joining a number of two-cell rectifiers in series. The capacity of a number of condensers is

$$\frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}\cdots}.$$

If, therefore, n similar two-cell rectifiers be put in series without changing the size of the plates the efficiency will be the same as that of one rectifier having a pair of plates $\frac{1}{n}$ times the size (because capacity and resistance in an electrolytic condenser are inversely proportional to each other)* but the ability to affect an impressed E. M. F. n times as great will be gained. If the plates in each rectifier be made n times as large as at first the efficiency of the series will be the same as that of any one of the original ones, and up to n times the voltage. The effect of n rectifiers in parallel is exactly the same * as that of one rectifier whose plates are n times the size of the individual plates. The number of rectifiers and the impressed E. M. F. should for the best result, be proportioned to their circuit as primary cells are proportioned, each primary cell being represented by a rectifier and a certain factor of the impressed E. M. F.

Effect of Inductance.—Inductance in series with a two-cell rectifier has two principal effects; it shifts backward the point at which rectification starts, and it changes the "effective" capacity (capacity available for choking the "useless" current). The theory is extremely complicated and will only be briefly touched upon here. The number of experiments made was insufficient to determine with certainty the correctness of the following, though the only data suitable for comparison (those of curves on the medium-sized plate at different frequencies and with different inductances) bear out the conclusions given.

In the ordinary alternating circuit capacity produces a lead, and inductance a lag. If inductance be added to a circuit having capacity its effect is to make the capacity appear larger. It may be taken as a general proposition that anything which increases

* True only when all the electrolyte is in a prism between the plates; in large masses of liquid small plates have less resistance per unit of capacity than large, due to the "spreading" of the current.

the angle of lead, φ, as shown previously, will increase the efficiency, and *vice versa*. In the present case the effect of the rectifier is to alternately insert and remove capacity from a self-inductive circuit, and at an instant later (because the current is lagged) than when the circuit had no self-induction. Calling the

Steady current through the circuit without capacity or inductance..... A
" " " " " with given capacity alone..... B
" " " " " given inductance alone C
" " " " " given capacity and inductance..... D

it is evident that C will be the current flowing at the end of a rectified period (instead of A, as in the former case), and that D (instead of B) will be the current whose value at the instant C passes through zero determines the size of the "useless." Let $\varphi_A =$ lead of $A = 0$, $\varphi_B =$ lead of B, etc., and assume the efficiency dependent on φ only. Then when $\varphi_A + \varphi_B > \varphi_C + \varphi_D$ inductance has decreased the efficiency obtainable when it is absent, when $\varphi_A + \varphi_B = \varphi_C + \varphi_D$ inductance has no effect, and when $\varphi_A + \varphi_B < \varphi_C + \varphi_D$ inductance has increased the efficiency. $\varphi = \varphi_A + \varphi_B$ in a non-inductive, and $\varphi = \varphi_C + \varphi_D$, in an inductive circuit.

If L denote the inductance, C the capacity, p the angular velocity, and R the resistance, then $\varphi_A = 0$, $\varphi_B = \tan^{-1}\frac{1}{pCR}$, $\varphi_C = \tan^{-1}\frac{pL}{R}$, and $\varphi_D = \tan^{-1}\left(\frac{1}{pCR} - \frac{pL}{R}\right)$. Assuming values for R, p, C, and L, and substituting, the following points are found:

Increasing the inductance in a balanced rectifier's circuit first increases φ, then decreases it. At resonance φ is the same as when there is no inductance in the circuit.

For constant size of plates the higher the frequency the smaller the inductance necessary to produce φ_{max}, and *vice versa*.

For constant frequency the larger the plates the smaller the inductance necessary to produce φ_{max}, and *vice versa*. The smaller the plates, or the lower the frequency, the greater the effectin ductance can produce.

In an underbalanced rectifier increasing inductance does not proportionately increase φ_C, and φ will be decreased by small inductance, increased by more inductance, and decreased by still more.

(For actual and theoretical effects see Figs. 3, 4 and 5, curves *a*, *b*, *c*, and *d*; *w*, *x*, *y*, and *z*; and *m* and *n*.)

When $\varphi_c + \varphi_p$ (or the "effective lead," whatever it may be) is greater than 90° no more effect is produced than when it equals 90°, because the condenser acts only during the "useless" flow.

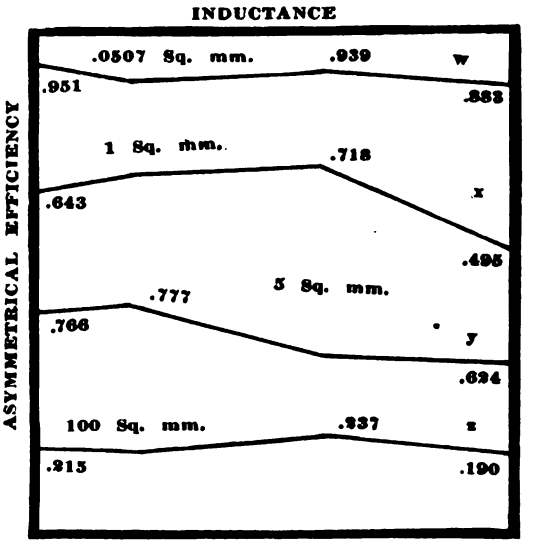

FIG. 3. Effect of Inductance and size of plate.

The "effective lead" is not the only factor in determining the efficiency. The "useful" is choked by the inductance, not as a simple alternating current would be choked, but to a degree dependent on the point of the "useful" at which the condenser's action ceased. The small capacity effect during the "useful," due to the overcharging of the plates, also plays a part. The form of the "useless" differs materially from that in non-inductive circuits, probably caused by the "insertion" of the capacity at a time when the inductance is partly charged; inductance causes the "useless" to approach the sine form, with a greater slope when decreasing than when increasing. In addition, oscillatory currents are produced when a charged condenser is inserted into an inductive circuit, the waves being of a frequency dependent on the values of L and C, and of an amplitude dependent on the condenser charge and the resistance. Such oscillations were not observed; their frequency would probably have been from about 15, with the largest capacity and inductance, to about 3000, with the smallest.

Actual Curves.—A few of the curves plotted on two-cell rectifiers in operation are shown in Fig. 6; the current and E. M. F.

are not plotted to the same scale. A list of conditions, etc., in some typical cases follows. The curves show most of the points

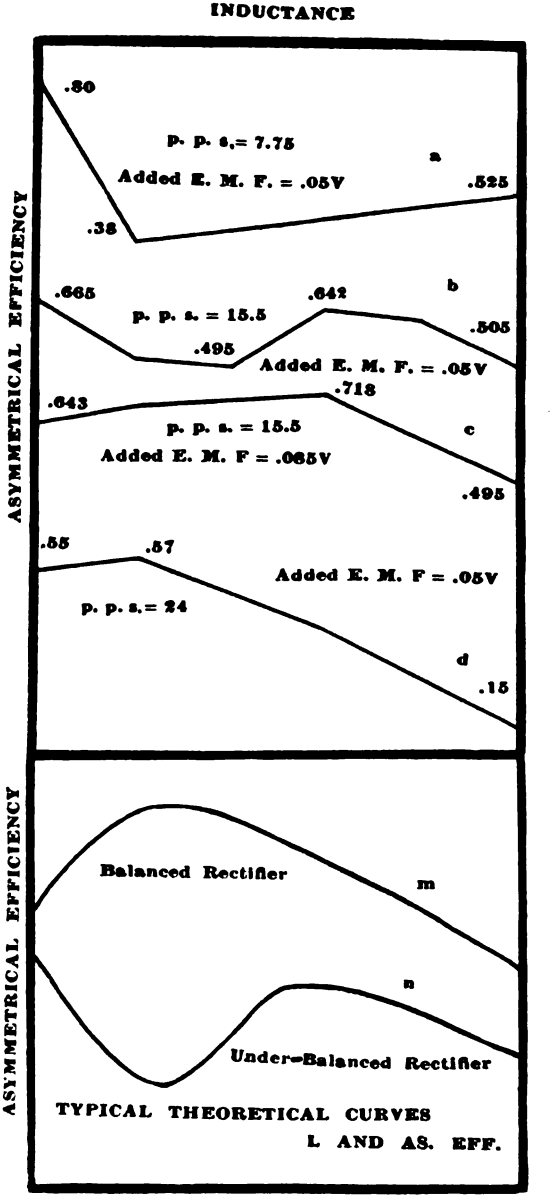

FIG. 4. Effect of Inductance and Frequency.

brought out in the "Conclusions," and will not be discussed in detail. The usual form of rectifier consisted of a Leclanché in series with two platinum points in acidulated (25% H_2SO_4) water. It was concluded that the E. M. F. of Leclanché was too low.

TABLE I.

CONDITIONS IN TWO-CELL RECTIFIERS.

No.	Arrangement.	Imp. E. M. F. Volts.	A. E.	mm. between electrodes.	Ext. Res. Ohms.	Object: To show effect of
1	H_2SO_4 between .0507 sq. mm. electrodes.....	5.3				Alternating Electrolysis.
2	Daniell Cell.....	1.6				Combined direct and alternating.
3	.0507 sq. mm. electrodes in H_2SO_4 in series with 1 Leclanché	1.6	.99	1	100	Area of electrodes.
4	.1465 sq. mm. electrodes in H_2SO_4 in series with 1 Leclanché	1.6	.82	1	100	" " "
5	1.975 sq. mm. electrodes in H_2SO_4 in series with 1 Leclanché	1.6	.74	1	100	" " "
6	6.410 sq. mm. electrodes in H_2SO_4 in series with 1 Leclanché	1.6	.66	1	100	" " "
7	6.41 and 1000 sq. mm. electrodes in H_2SO_4, 1 Leclanché, 641 to — pole	1.6	.15	—	100	" " "
8	6.41 and 1000 sq. mm. electrodes in H_2SO_4, 1 Leclanché, 6.41 to + pole	1.6	.24	—	100	" " "
9	6.41 sq. mm. electrodes in series with 1 Leclanché	1.6	.77	1	25	External resistance.
6	6.41 sq. mm. electrodes in series with 1 Leclanché	1.6	.66	1	100	" "
10	6.41 sq. mm. electrodes in series with 1 Leclanché	1.6	.61	1	300	" "
11	6.41 sq. mm. electrodes in series with 1 Leclanché	1.6	.11	1	5000	" "
12	6.41 sq mm. electrodes in series with 1 Leclanché	1.6	.72	30	100	Internal "
13	6.41 sq. mm. electrodes in series with 2 Leclanché	1.6	—	1	100	Active E. M. F. to high.
14	6.41 sq. mm. electrodes in series with 1 Leclanché	.75	.39	1	100	Impressed E. M. F.
15	6.41 sq. mm. electrodes in series with 1 Leclanché	2.5	.34	.30	100	" "
16	6.41 sq. mm. electrodes in series with 1 Leclanché	4.0	.25	1	100	" "
17	.0507 sq. mm. electrodes in series with 1 Leclanché	4.0	.59	1	100	" "
18	Same as in 6; frequency 28⅓ pp. s.....	1.6	.57	1	100	Increased frequency.

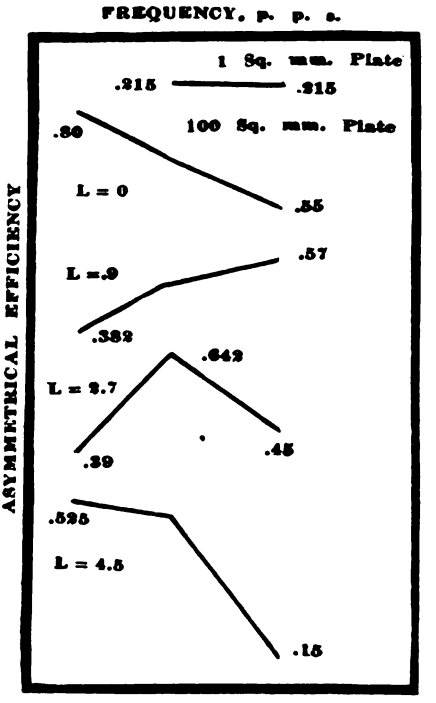

FIG. 5. Effect of Frequency and Inductance.

To determine the true forms of the various curves under the most favorable conditions a series of curves was taken on a hydrogen single-cell rectifier (Fig. 7) whose theory, considered in Part II., will be found exactly the same as that of the two-cell rectifier. The action, taking place at one electrode only, is more easily analyzed, and purer, than in the two-cell form; the electrolyte can be maintained perfectly free from oxygen, and all the conditions, except that of the electrode surface, maintained absolutely constant for any length of time. The electrode surface gradually becomes covered with finely divided platinum, perhaps torn from its own surface (an effect long known to be produced by pulsating currents), perhaps deposited from a slow solution of the other electrode. This makes curves taken some time apart not comparable, the asymmetrical efficiency decreasing with age. A comparatively fresh 5 sq. mm. electrode for example, was found to give a considerably higher efficiency than an old 1 sq. mm. electrode (see Table 3). Curves taken on several electrodes at different ages

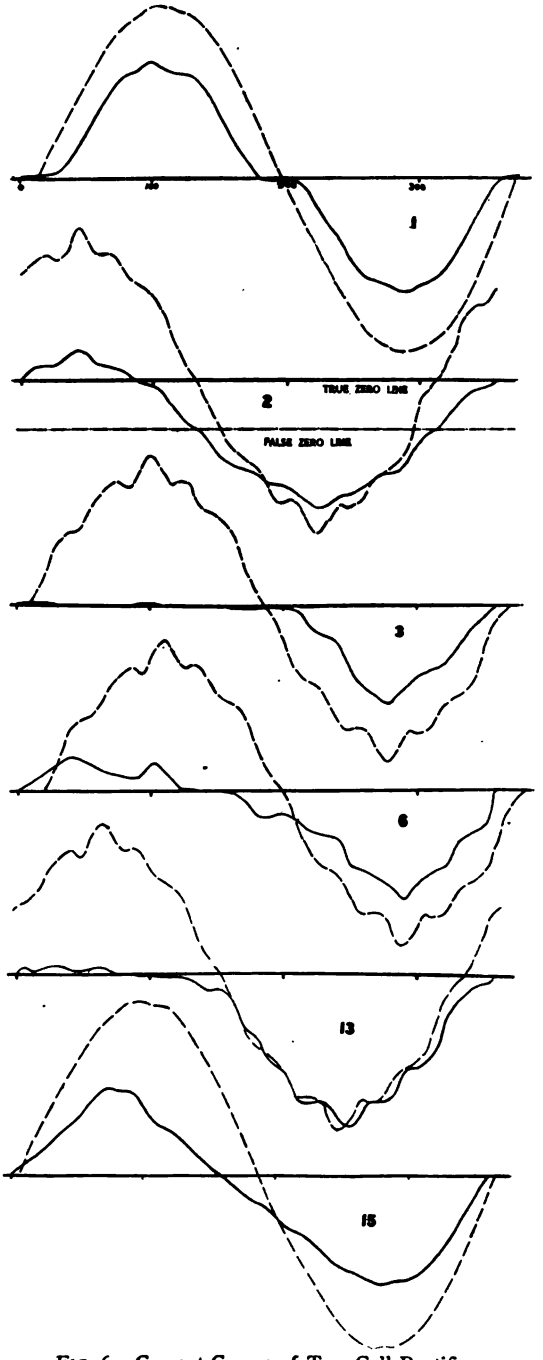

FIG. 6. Current Curves of Two Cell Rectifier.

showed continuously decreasing efficiencies. It was found that the extra E. M. F. needed to exactly balance cell differed with the size of the electrodes. With the greater number of 1 sq. mm. electrode curves the added E. M. F. was about 0.35 V too low; though this does not change the main characteristics of the curves it makes some obvious, but slight, modifications necessary where a comparative study is made. For the smallest electrodes, and for one set of 1 sq. mm. electrode readings, the cells are almost exactly balanced; for the others it was underbalanced.* The construction of the testing cell follows:

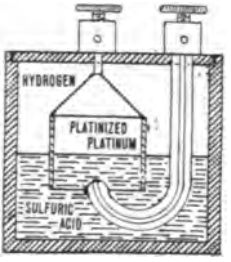

FIG. 7.

Wide-mouthed, half-pint bottle closed with three-hole rubber stopper, and kept under water seal. Electrolyte; $\frac{1}{8}$ H_2SO_4, thoroughly boiled to remove air. Hydrogen admitted and liquid expelled through a tube through stopper. Large electrode, platinized; 3000 sq. mm., formed of tissue foil stiffened with wire at upper edge. Distance between nearest points of electrodes; about 10 mm. With small

(A) Electrode .0507 sq. mm. area, cell resistance† about 90 ohms

(B) " 1 " " " " " 25 "
(C) " 5 " " " " " 15 "
(D) " 100 " " " " " 2 to 5 "

The accuracy of the curves of Table 2, some of which are shown in Fig. 8, is such that when plotted to a scale of 9 inches per period the curve passed through the points found. The curves of Fig. 8 is more or less typical in shape, and show the general form of the curves not illustrated.

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* See also "Continuous-Acting Rectifiers," Part II.

† Found by putting cell and ammeter in series with direct E. M. F., and inserting sufficient resistance to halve reading, taking readings with brief closures of the circuit. Then: Final external resistance — Twice original external resistance = Resistance of cell. Method checks for various external resistances, if closures are very brief; otherwise apparent resistance is too high, and increases with decreasing external resistance.

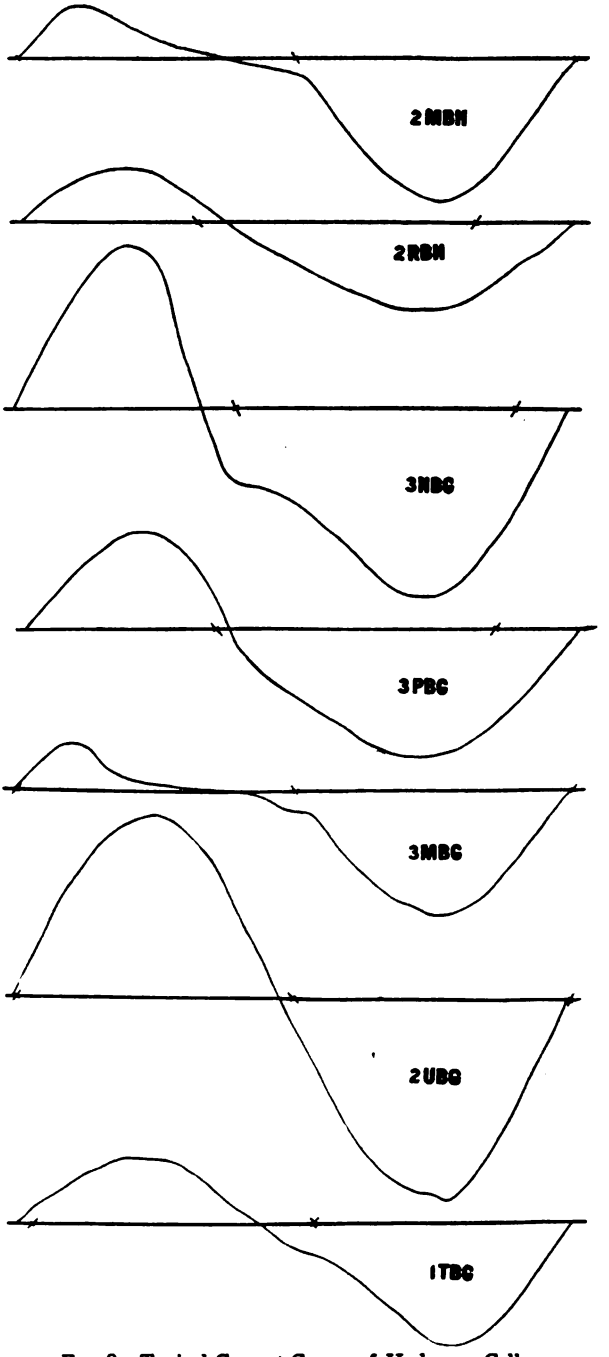


FIG. 8. Typical Current Curves of Hydrogen Cell.

Type Curve Fig. 8.	Curves not Illustrated.							
2 MBH	2 MBG	2 mBG	1 mBG	1 MBG	2 MCG	2 NCG	6 MDF	2 MA(O)
2 RBH	2 RDF	2 PDF	2 rBG	6 RDF	2 rDF	2 NDF		
3 NBG	2 PCG	2 nBG	2 OBG	2 RBG	2 RCG			
3 PBG	2 PBG	2 QBG	2 RBG	2 MDF				
3 MBG	2 MBG	2 PAH	2 RAH					
2 UBG	1 UBG	2 SBG	2 TBG	2 (RU)BG				
1 TBG	1 SBG							

The remainder of the illustrated curves (Fig. 9) show points of interest which it is unnecessary, in most cases, to indicate. The only ones which do not seem to be satisfactorily explained are those having four zero-points (4 *MBG*), (2 *NBH*), and (2 *NBG*). (6 *MBG*) is extremely interesting in that it shows a sudden drop, indicative of a rise in the polarization, of approximately .42 volts within .0014 seconds. To this must be added about .05 volts for the rise in the impressed E. M. F., giving a quantity approaching, in magnitude, the difference between the counter E. M. F.'s given by oxygen in the form of O and as OH, and indicating the production of oxygen gas. Less sharp drops, shown in several other curves, are believed to be due to other causes. No such drop is shown in (6 *MDF*) or in (6 *mDF*), the plate being too large for a rapid rise in polarization.

Use of High Frequencies.—The frequencies used in the curve-tracing ranged from about 7 to about 28 periods per second. At frequencies ranging from about 200 to 750 periods current readings on the low-reading voltmeter (used as an ammeter) were taken, but, for obvious reasons, no curves were traced. Two-cell and single-cell rectifiers were found to work well even at 750 p. p. s., and to show the same general results as at low frequencies. The use of high frequencies permitted a very high impressed E. M. F. to be used, giving large readings on the direct-current instrument. With a hydrogen cell, balanced by a small direct E. M. F., the current readings were reduced to less than half by doubling the external resistance. With even a large external resistance doubling the inductance reduced the readings to less than half. Even with an inductance of 2.7 a small reading was observable at the highest frequencies mentioned above. The larger the inert plate the higher the reading obtainable. Within limits readings proportionate to the E. M. F. could be obtained.

The effect of the frequency could be very prettily shown by put-

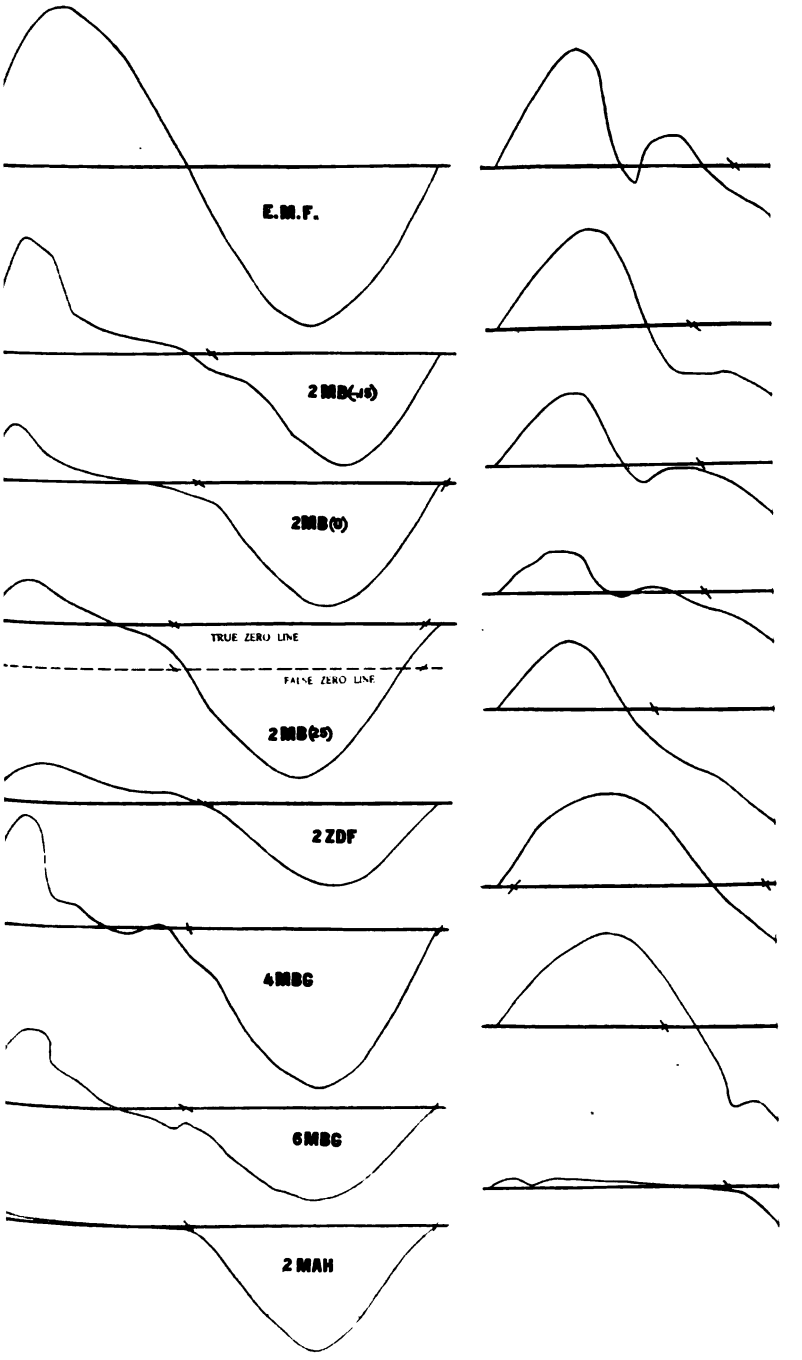


FIG. 9. Odd-shaped Current Curves of Hydrogen Cell.

ting a large inductance in the alternator circuit and taking the current for the cell from a dead resistance in series with it. The resistance being negligible, the inductance kept the current, and consequently the E. M. F., impressed on the cell, practically constant between about 30 and 750 p. p. s. On shutting current from the driving motor the needle of the ammeter gradually rose with the decreasing speed, to sometimes as much as ten times the original reading. Inductance in the cell circuit increased the difference between the two readings; the size of the passive plate also had considerable effect on the difference.

MEAN EFFECTIVE TEMPERATURE A UNIT OF COMPARISON FOR HEAT ENGINES.

By CHARLES E. LUCKE.

It has been the custom to designate especially as heat engines those machines not operated by steam or any other vapor. Under this head there come what are known as gas and hot air engines. These latter derive their power from the expansion of a mass of heated gas, be this pure air or a mixture of various perfect gases. For the purposes of comparison and differentiation, the various heat engines have been classified into cycles, a cycle being a continuous series of operations performed upon and by the working gas. These cycles depend for their points of similarity on the fact that work is done by the expanding of a perfect gas which has received heat in some particular manner, and for their differences on that manner of application.

Heat applied to a mass of gas will primarily increase one or more of its three parameters, usually two of them, the other remaining constant, which is possible since

$$pv = RT$$

where p = pressure, v = volume, T = temperature

and $R = \left(\frac{p'v'}{T'}\right)$ for any other state of the gas.

Since there are three quantities involved we have then, three typical modes of applying heat, —

1° at constant volume

TABLE 2.

DATA OF HYDROGEN-CELL CURVES.

Curve No.	Electrode Area sq mms.	Added Volts.	Frequency p. p. s.	Ext. Res. Ohms.	Inductance Henrys.	Alternating Voltage.	Asym. Eff. %	Lead Degree.	Degree Length "Useless."	Degree Length "Useful."	Amplitude "Useless" / "Useful."	Object: To show effect of
E. M. F.			15½		0		0		180	180	1.000	
2 MB(—.15)	1	—15	15½	100	0	.455	11.7	+19.0	180	180	1.035	Added Direct E. M. F.
2 MB(0)	1	0	15½	100	0	.455	59.7	+ 6.0	145	215	.448	" " "
2 MB(+.25)	1	+.25	15½	100	0	.455	74.0	—12.5	124	236	.273	" " "
2 MA(0)†	.0507	0	15½	100	0	.455	80.0	+ 9.5	158	202	.103	" " "
2 MAH†	0507	+.085	15½	100	0	.455	95.1	0	138	222	.045	" " "
2 MBG	1	+.05	15½	100	0	.455	66.5	+ 1.5	142	218	.363	External Resistance.
2 SBG	1	+.05	15½	500	0	.455	20.4	+ 1.5	167	193	.763	" "
2 TBG	1	+.05	15½	1000	0	.455	16.0	+ 4.0	168	192	.792	" "
2 UBG	1	+.05	15½	10000	0	.455	8.3	+ 3.0	173	187	.901	" "
1 MBG	1	+.05	15½	100	0	.228	63.5	+16.0	156	204	.221	" "
1 SBG	1	+.05	15½	500	0	.228	42.4	+12.0	156	204	.432	" "
1 TBG	1	+.05	15½	1000	0	.228	34.0	+12.0	159	201	.535	" "
1 UBG	1	+.05	15½	10000	0	.228	15.0	+ 8.5	168	192	.811	" "
2 ZDF	100	+.01	15½	10	0	.455	34.9	+11.0	189	171	.476	" "
2 MDF	100	+.01	15½	100	0	.445	21.5	+11.5	159	201	.735	" "
1 MBG	1	+.05	15½	100	0	.228	63.5	+16.0	156	204	.221	Impressed E. M. F.
2 MBG	1	+.05	15½	100	0	.455	66.5	+ 1.5	142	218	.363	" "
3 MBG	1	+.05	15½	100	0	.683	72.2	+ 1.0	140	220	.355	" "
4 MBG	1	+.05	15½	100	0	.910	49.0	+ 1.5	124+14	28+194	.695	" "
6 MBG	1	+.05	15½	100	0	1.365	35.5	+ .5	131	229	.808	" "
2 MDF	100	+.01	15½	100	0	.455	21.5	+11.5	159	201	.735	" "
6 MDF	100	+.01	15½	100	0	1.365	19.1	0	164	196	.751	" "
2 RDF*	100	+.01	15½	200	4.5	.455	19.0	—57.5	163	197	.822	" "
6 RDF*	100	+.01	15½	140	4.5	1.365	20.2	—68.8	160	200	.801	" "
2 MBG	1	+.05	7¾	100	0	.455	80.0	+ 2.5	150	210	.242	Frequency.
2 MBG	1	+.05	15½	100	0	.455	66.5	+ 1.5	142	218	.363	"
2 mBG	1	+.05	24	100	0	.455	55.0	+ 1.5	139	221	.507	"
1 MBG	1	+.05	7¾	100	0	.228	71.5	+18.0	167	193	.174	"
1 MBG	1	+.05	15½	100	0	.228	63.5	+16.0	156	204	.221	"
2 MBG	1	+.05	7¾	100	9	.455	80.0	+ 2.5	150	210	.242	Inductance and Frequency.
2 NBG	1	+.05	7¾	100	.9	.455	38.5	—13.0	91+45	13+211	.850	" " "
2 PBG	1	+.05	7¾	100	2.7	.455	45.1	—39.0	109	251	.844	" " "
2 RBG*	1	+.05	7¾	140	4.5	.455	52.5	—49.0	114	246	.761	" " "

2 NBG	1	+.05	15½	100	.9	.455	52.1	−31.0	94	200	.714	
2 OBG	1	+.05	15½	100	1.8	.455	49 5	−51.0	112	248	.696	" " "
2 PBG	1	+.05	15½	100	2.7	.455	64.2	−67.0	102	258	.560	" " "
2 QBG *	1	+.05	15½	120	3.6	.455	61.8	−66.0	107	253	.536	" " "
2 RBG * §	1	+.05	15½	140	4.5	.455	50.5	−67.0	126	234	.611	" " "
2 MBH	1	+.085	15½	100	0	.455	64.3	0	136	224	.350	" " "
2 NBH	1	+.085	15½	100	.9	.455	69.3	−31.0	78+33	17+232	.447	" " "
2 PBH	1	+.085	15½	100	2.7	.455	71.8	−68.0	93	267	.477	" " "
2 RBH * §	1	+.085	15½	140	4.5	.455	49.5	−65.0	135	225	.609	" " "
2 mBG	1	+.05	24	100	0	.455	55.0	+ 1.5	139	221	.507	" " "
2 nBG	1	+.05	24	100	.9	.455	57.0	−40.0	102	258	.686	" " "
2 pBG	1	+.05	24	100	2.7	.455	39.0	−59.0	143	217	.700	" " "
2 rBG *	1	+.05	24	140	4.5	.455	15.0	−55.0	158	202	.885	" " "
3 MBG	1	+.05	15½	100	0	.683	72.2	+ 1.0	140	220	.355	Inductance and E. M. F.
3 NBG	1	+.05	15½	100	.9	.683	55.0	−34.0	122	238	.877	" " "
3 PBG *	1	+.05	15½	100	2.7	.683	40.0	−55.0	133	227	.753	" " "
2 (RU) BG	1	+.05	15½	10000	4.5	.455	9.9	+ 4.0	171	189	.907	Inductance and Resistance.
2 MAH †	.0507	+.085	15½	100	0	.455	95.1	0	138	222	.045	Size of Plates.
2 MBH	1	+.085	15½	100	0	.455	64.3	0	136	224	.350	" " "
2 MCG	5	+.05	15½	100	0	.455	76.6	+ 3.5	162	198	.158	" " "
2 MDF	100	+.01	15½	100	0	.455	21.5	+11.5	159	201	.735	" " "
2 MAH †	.0507	+.085	15½	100	0	.455	95.1	0	138	222	045	Size of Plates and Inductance.
2 NAH †	0507	+.085	15½	100	.9	.455	91.3	−20.0	140	220	.059	" " " " "
2 PAH * †	.0507	+.085	15½	120	2.7	.455	93.9	−28.0	80+	250+	.100	" " " " "
2 RAH * §	.0507	+.085	15½	140	4.5	.455	88.3	−38.0	90+	250+	.218	" " " " "
See	also	set	of	curves	above	2 MBG	to	2 RBG	inc			" " " " "
2 MCG	5	+.05	15½	100	0	.455	76.6	+ 3.5	162	198	.158	" " " " "
2 NCG	5	+.05	15½	100	.9	.455	77.7	−17.0	123	237	.254	" " " " "
2 PCG	5	+.05	15½	100	2.7	.455	64.4	−53.0	100	260	.490	" " " " "
2 RCG *	5	+.05	15½	200	4.5	.455	62.4	−57.0	105	255	.511	" " " " "
2 MDF	100	+.01	15½	100	0	.455	21.5	+11.5	159	201	.735	" " " " "
2 NDF	100	+.01	15½	100	.9	.455	20.1	−25.0	153	207	.901	" " " " "
2 PDF	100	+.01	15½	100	2.7	.455	23.7	−52.0	157	203	.807	" " " " "
2 RDF * §	100	+.01	15½	140	4.5	.455	19.0	−57.5	163	197	.822	" " " " "
2 mDF	100	+.01	24	100	0	.455	21.5	+12.5	155	205	.755	Size of Plates and Frequency.
2 rDF *	100	+.01	24	200	4.5	.455	14.3	−61.0	168	192	.888	" " " " "

1st Numeral represents Impressed E. M. F.
1st Letter represents Resistance or Inductance.
Type of 1st Letter represents Frequency.
2d Letter represents Electrode Area.
3d Letter, or Bracketed Numerals, represents Added Direct E. M. F.

* External Resistance added necessary to obtain sufficient drop for measurement.
† "Useless" probably inaccurate because of small drop obtainable.
§ Probably inaccurate because of small drop obtainable.

2° at constant pressure

3° at constant temperature :

By previously compressing the gas we might get three more in a similar manner. Of these six only four are available for work.

a.—Without compression, addition of heat at constant volume.

b.—With compression, addition of heat at constant volume.

c.—With compression, addition of heat at constant pressure.

d.—With compression, addition of heat at constant temperature.

We shall designate these in the order named, Cycle I, Cycle II, Cycle III, Cycle IV. In every case expansion adiabatically will follow the addition of heat.

We might calculate from a knowledge of the amount of heat added according to any cycle, the work done and the work or energy carried off in the exhaust; but experiments show these calculations are never representative of the true state of affairs, in an actual engine there are various important losses besides the exhaust.

These losses not appearing in the theoretical calculation are due chiefly to 1° heat conducted through the cylinder walls and then radiated, and 2° dissociative absorption of heat in the mass of gas itself.

Conduction through the cylinder depends on the character of the surface and the temperatures on opposite sides, and is given by Rankine as $q = \frac{(T' - T)^2}{a}$ = rate of conduction per square foot, per hour, where T is the temperature of the air, and a a constant depending on the surface. For any given cylinder we see that q will depend on a second power of the temperature inside. The heat conducted through is immediately radiated into space.

Dissociation of the molecules of a mass of gas takes place only at high temperatures. This fact we know from experience but exact data as to when it commences for the various gases with the amount thus absorbed and the amount subsequently given up again if any, are almost entirely lacking.

Berthelot in his work on explosives notes that with high temperatures N and O will form some nitrogen oxides with considerable absorption of heat. Instances with other elements are also recorded. It is a well known fact that compound gases may be decomposed at high temperatures and in so doing absorb heat.

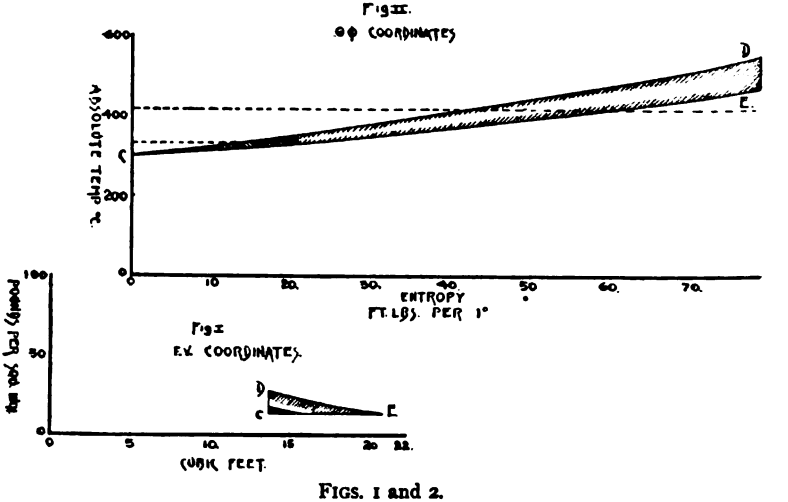
We have then within the gas itself two causes of loss due to high temperatures: 1° A dissociative, separating compounds and pre-

venting molecules which would combine if free, from doing so, *i. e.*, O and H to form H_2O, O and C to form CO and CO_2. 2° The formation of compounds with absorption of heat, *i. e.*, N and O to form NO, etc.

Since, therefore, the chief causes of loss from the cylinder conduction, radiation, and dissocration are functions of the temperature therein, it is obviously important that we should study the temperatures and their variations through the various cycles. The temperature of the mass of gas through any one cycle will vary, but according to some law and if we would compare this cycle with another some characteristic or defining temperature becomes desirable. This characteristic temperature determined by application of the laws of the cycle we shall call the mean effective temperature of that cycle.

If heat be applied at constant volume without previous compression we have Cycle I, see Figs. I. and II.

CYCLE I DIAGRAMS.



FIGS. 1 and 2.

Let H_1 = Heat supplied.

C_v = Specific heat at constant volume.

T_a = Temperature degrees Centigrade absolute after addition of heat.

t = Temperature before = temperature of atmosphere.

Then $$H_1 = C_v(T_d - t)$$

or $$T_d = t + \frac{H_1}{C_v}.$$

The pressure due to this rise

$$p_d = 14.7\,\frac{T_d}{t} = 14.7\left(1 + \frac{H_1}{C_v t}\right).$$

Allow the gas to expand adiabatically to atmosphere, then,

$$p_d v_d^\gamma = p_e v_e^\gamma = 14.7\, v_e^\gamma \quad \text{where} \quad \gamma = 1.406 = \frac{C_p}{C_v}$$

$$\therefore V_e = \left(\frac{p_d}{p_e}\right)^{\frac{1}{\gamma}} v_d. \quad \text{But} \quad \frac{p_d}{p_e} = \frac{T_d}{t}$$

$$= 1 + \frac{H_1}{C_v t}.$$

$\therefore$ Final volume $$Ve = \left(1 + \frac{H_1}{C_v t}\right)^{\frac{1}{\gamma}} v_d$$

Since final pressure is equal to the original

$$\frac{T_e}{t} = \frac{V_e}{V_d} \quad \text{or} \quad T_e = t\,\frac{V_e}{V_d},$$

But $$\frac{V_e}{V_d} = \left(1 + \frac{H_1}{C_v t}\right)^{\frac{1}{\gamma}}$$

$$\therefore T_e = t\left(1 + \frac{H_1}{C_v t}\right)^{.711} \quad \text{where} \quad \frac{1}{\gamma} = .711.$$

which is the final temperature in terms of the original amount of heat supplied.

The work done = W_1.

$$\therefore W_1 = 2.463\, p_d v_a \left\{\left(\frac{V_d}{V_e}\right)^{\gamma-1} - 1\right\}.$$

See Kent p. 501.

or if H_2 = heat carried off in exhaust

$$W_1 = H_1 - H_2 = H_1 - C_p(T_e - t)$$

$$= H_1 - C_p t\left[\left(1 + \frac{H_1}{C_v t}\right)^{\frac{1}{\gamma}} - 1\right].$$

In $O\varphi$ coördinates for addition of heat at constant volume the entropy range

$$\varphi_1 - \varphi_2 = C_v \log_e \left(\frac{T_d}{t}\right) = C_v \log_e \left(1 + \frac{H_1}{C_v t}\right).$$

If we define the mean temperature T_1 during addition of heat, as that temperature which, multiplied by the entropy range $(\varphi_1 - \varphi_2)$ gives the heat transformed during addition, then,

$$T_1 = \frac{H_1}{C_v \log_e \left(1 + \frac{H_1}{C_v t}\right)}.$$

Adiabatic expansion is a vertical on the $O\varphi$ diagram from T_d to T_e where T_e lies on a C_p curve drawn from t representing the cooling line of the gas after exhausted from the cylinder into the atmosphere.

Here we have as mean temperature of cooling

$$T_2 = \frac{C_p t \left[\left(1 + \frac{H_1}{C_v t}\right)^{\frac{1}{\gamma}} - 1\right]}{C_v \log_e \left(1 + \frac{H_1}{C_v t}\right)} = \gamma \frac{t\left[\left(1 + \frac{H_1}{C_v t}\right)^{\frac{1}{\gamma}} - 1\right]}{\log_e \left(1 + \frac{H_1}{C_v t}\right)}.$$

Using these mean temperatures we might transform the curved lines of the $O\varphi$ diagram to straight lines and the irregular areas will become rectangles. The rectangular areas of Fig. III are equal to those bounded by curves originally.

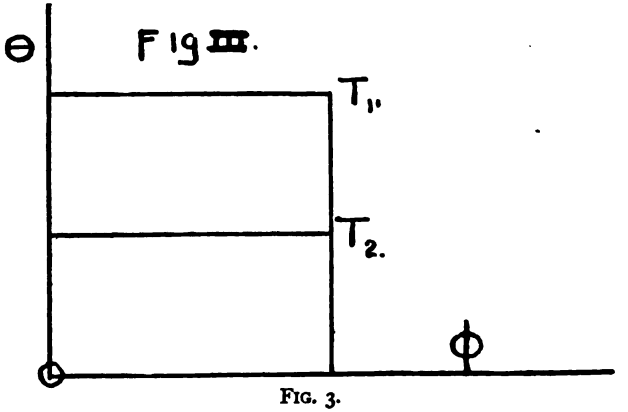


FIG. 3.

If we had taken the mean effective temperature analogous to mean effective pressure we should have obtained the height $\overline{T_1\ T_2}$ which multiplied by the entropy range would give the work done.

A range of x pounds, mean effective pressure, will give the same work and identical effects whether lying between $a + x$ and a or between $b + x$ and b, *i. e.*, it makes no difference where on the pressure scale the mean effective pressure range lies, so far as the work done is concerned.

In the scale of temperatures, however, a range of y degrees will depend for its dissociative, conductive, and radiation effects on what

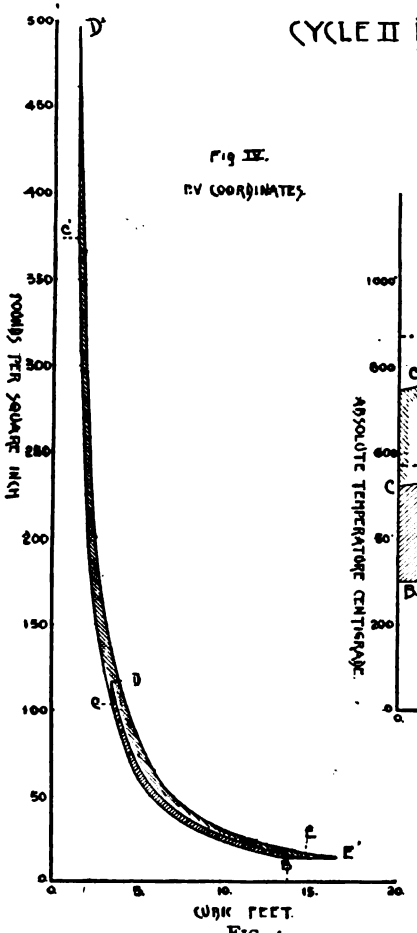


FIG. 4.

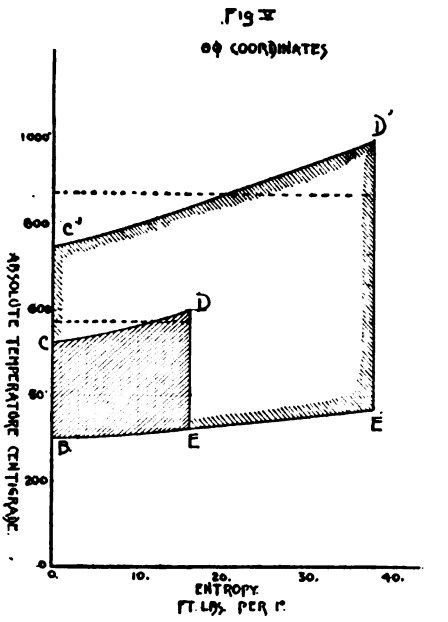


FIG. 5.

part of the scale we consider. Taking $M.E.T. = \dfrac{W}{\varphi_1 - \varphi_2}$ we get $\left(\overline{T_1 T_2}\right)^\circ$ without any indication where on the scale it belonged. It is necessary then to choose some lower limit and suppose the

value just given measured up from this limit; the sum we shall call the Mean Effective Temperature of the cycle, taking for the lower limit T_2 equal to the mean temperature of the cooling line for all cycles.

The Mean Effective Temperature then will be the sum of two quantities T_2 and $(T_1 - T_2)$, or T_1 where $T_1 = M.E.T. = \dfrac{H_1}{\varphi_1 - \varphi_2}$.

We found for Cycle I

$$T_1 = M.E.T. \frac{H_1}{C_v \log_e \left(1 + \dfrac{H_1}{C_v t}\right)}.$$

CYCLE II. FIG. IV and V.

Heat added at constant volume after compression adiabatically.

$T_c = t \left(\dfrac{V_d}{V_c}\right)^{\gamma-1} = t(R)^{\gamma-1}$ where R = ratio of compression volumes.

$$H_1 = C_v(T_d - T_c)$$

or
$$T_d = \frac{H_1}{C_v} + T_c = \frac{H_1}{C_v} + tR^{\gamma-1}$$

$$\frac{T_d}{T_c} = \frac{H_1}{C_v T_c} + 1 = \frac{H_1}{C_v t R^{\gamma-1}} + 1$$

$$\varphi_1 - \varphi_2 = C_v \log_e \frac{T_d}{T_c}$$

$$= C_v \log_e \left(\frac{H_1}{C_v t R^{\gamma-1}} + 1\right)$$

$$M.E.T. = \frac{H_1}{\varphi_1 - \varphi_2}$$

$$= \frac{H_1}{C_v \log_e \left(\dfrac{H_1}{C_v t R^{\gamma-1}} + 1\right)}.$$

CYCLE III. FIG. VI. and VII.

Heat added at constant pressure after compression adiabatically.

$$H_1 = C_p(T_d - T_c)$$

$$\therefore T_d = \frac{H_1}{C_p} + T_c$$

$$\therefore \frac{T_d}{T_c} = \frac{H_1}{C_p t R^{\gamma-1}} + 1$$

$$\varphi_1 - \varphi_2 = C_p \log_e \left(\frac{H_1}{C_p t R^{\gamma-1}} + 1 \right)$$

CYCLE III DIAGRAMS

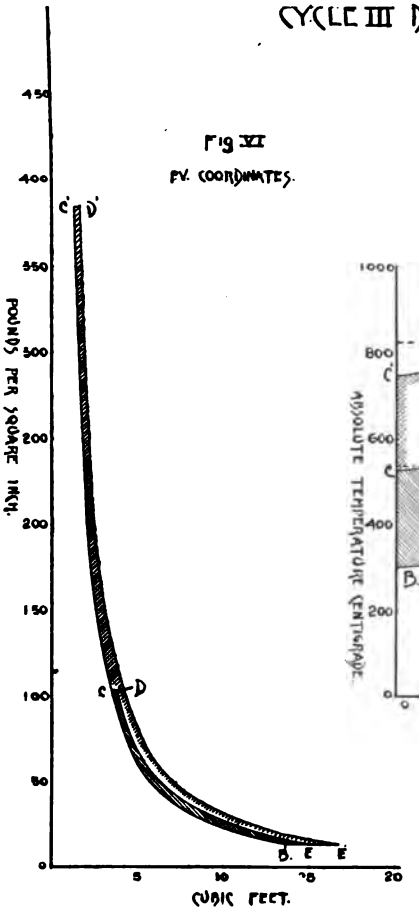


FIG. 6.

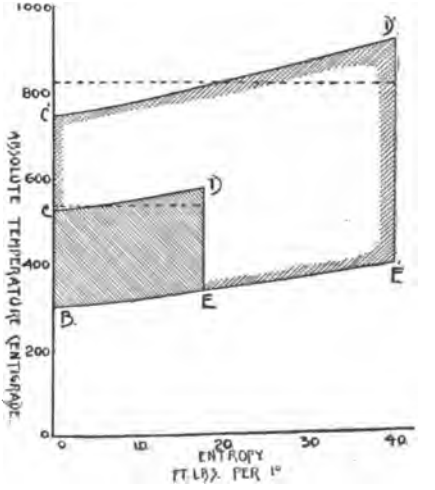


FIG. 7.

$$\therefore M.E.T = \frac{H_1}{C_p \log_e \left(\frac{H_1}{C_p t R^{\gamma-1}} + 1 \right)}.$$

CYCLE IV. FIG. VII. VIII.

Heat supplied at constant temperature after compression adiabatically.

$$T_c = T_d$$

$$\varphi_1 - \varphi_2 = \frac{H_1}{T_c} = \frac{H_1}{T_d} = \frac{H_1}{tR^{\gamma-1}}$$

$$M.\ E.\ T = \frac{\frac{H_1}{H_1}}{tR^{\gamma-1}} = tR^{\gamma-1}.$$

Collecting these formulæ we have for mean effective temperatures in terms of heat supplied and initial conditions.

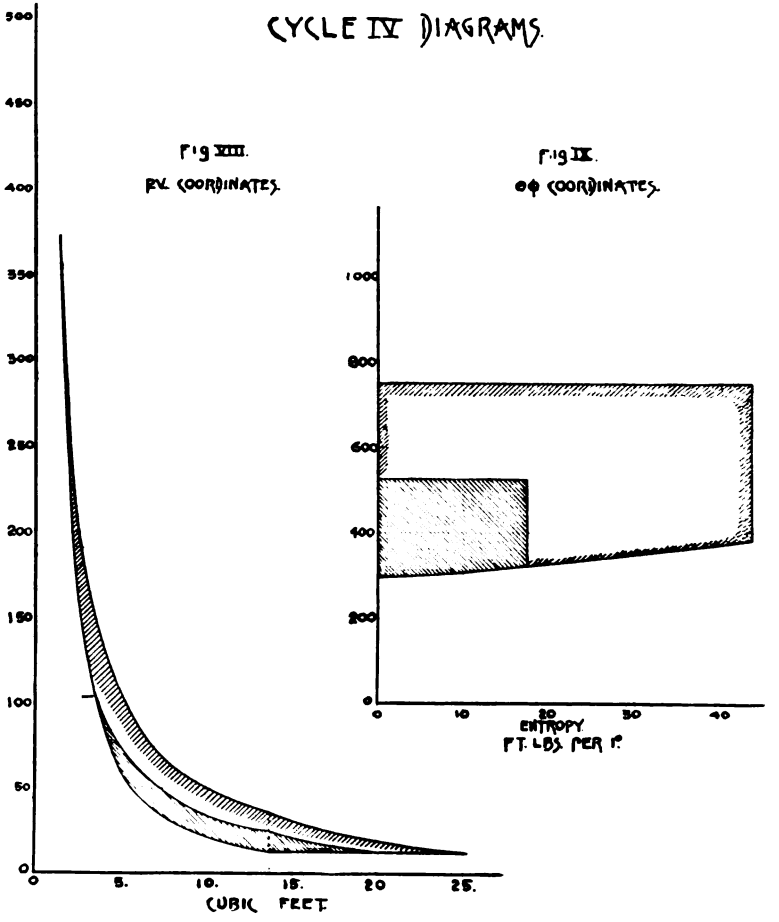


FIG. 8. FIG. 9.

Cycle	*M. E. T*	*Type*
I	$\dfrac{H_1}{C_v \log_e \left(\dfrac{H_1}{C_v t} + 1\right)}$	Lenoir Engine

II $$\frac{H_1}{C_v \log_e \left(\frac{H_1}{C_v t R^{\gamma-1}} + 1 \right)}$$ Perfect Otto Engine

III $$\frac{H_1}{C_p \log_e \left(\frac{H_1}{C_p t R^{\gamma-1}} + 1 \right)}$$ Brayton Engine

IV $$tR^{\gamma-1}$$ Diesel Engine

We might have derived a similar set in terms of final conditions.

The preceding diagrams were calculated on a comparison basis, and the mean effective temperatures are indicated on the $O\varphi$ diagrams by dotted lines.

In general for the same amount of heat supplied after compression, Cycle IV has lowest mean effective temperature while the other cycles come in the order III, II, while cycle I has lowest for all.

Let us next see how we can use an ordinary indicator card for the determination of its mean effective temperature.

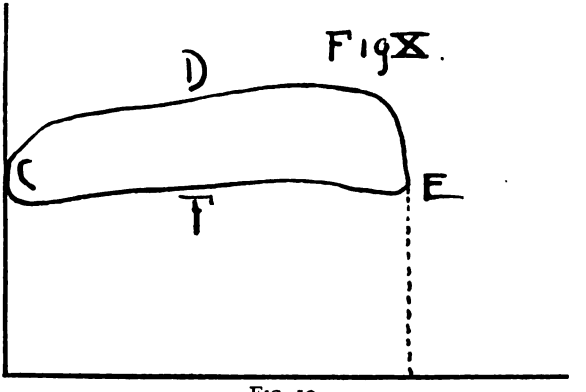


FIG. 10.

Let Fig. 10 be a $O\varphi$ diagram, then *EFC* is curve along which the gas loses heat at varying temperatures and through an entropy range equal to that of the curve *CDE* along which heat is added. If the entropy range for either curve is known it is known for the cycle. When the left hand end of the diagram is taken as the origin of φ coördinates then the entropy range is equal to the abscissa of the extreme right hand point *E*.

The expansion line of each cycle will in actual indicator cards be (*a*) adiabatic, (*b*) above an adiabatic, *i. e.*, heat being added

during expansion, or (*c*) below an adiabatic *i. e.*, heat being abstracted during expansion.

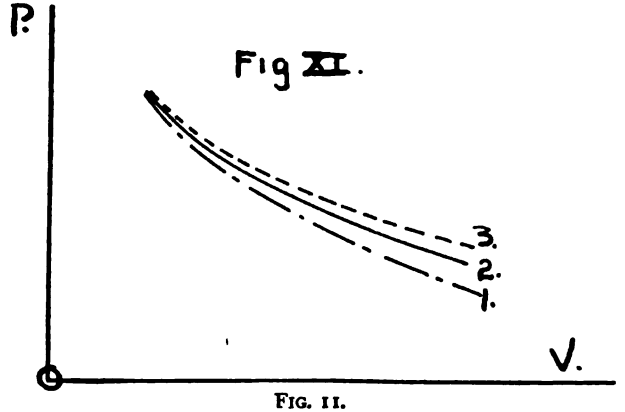


FIG. 11.

The point 1, 2 or 3, Figs. 11 and 12, the end of expansion will be the extreme right hand end of the indicator diagram. It will be

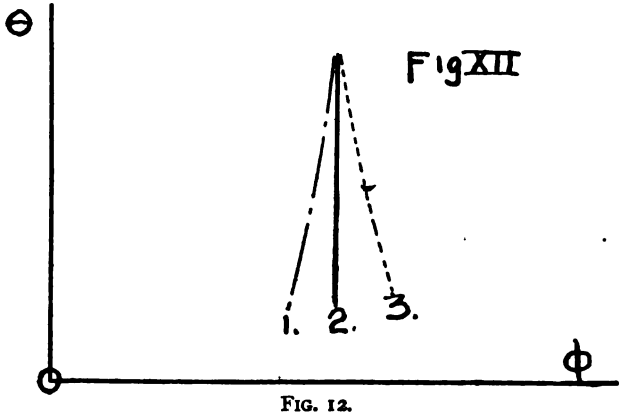


FIG. 12.

the extreme right of the $O\varphi$ diagram when the expansion has been adiabatic or above an adiabatic, *i. e.*, gas receiving heat. This latter is the case with all gas engines.

In such a card as is shown in Fig. XIII taken from a test of a Nash engine we might find the temperature of the point E at the end of expansion from

$$T_e = \frac{p_e v_e}{R} \text{ where } R = \frac{pv}{T} \text{ for any other state}$$

of the gas, whence

$$\varphi_1 - \varphi_2 = C_p \log_e \frac{T_e}{T_a};$$

T_a = temp. of atmosphere, or if at the point B, $T_b = T_a$,

$$\varphi_1 - \varphi_2 = C_p \log_e \frac{V_e}{V_b}.$$

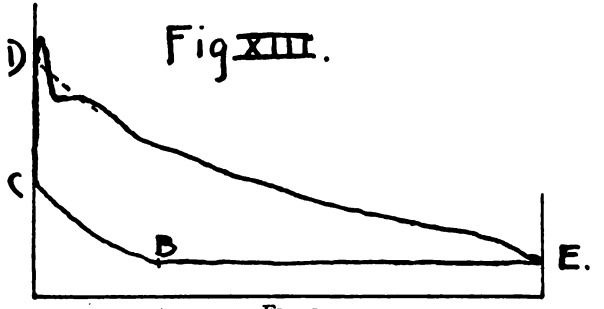


FIG. 13.

The heat discharged $H_2 = C_p (T_e - T_a)$

$$= C_p T_a \left(\frac{T_e}{T_a} - 1\right).$$

If $T_b = T_a$

$$H_2 = C_p T_a \left(\frac{V_e}{V_b} - 1\right).$$

Work done W is measured by the planimeter.

$H_1 = W + H_2$

$$\therefore M.\ E.\ T. = \frac{W + C_p T_a \left(\frac{V_e}{V_b} - 1\right)}{C_p \log_e \left(\frac{V_e}{V_b}\right)}$$

in terms of quantities measurable from the $p.\ v.$ card.

A study of compared cards will form the subject for a second paper.

THE ASSAY PRACTICE OF THE WEST COMPARED WITH THAT OF THE SCHOOL OF MINES.

By CHARLES FULTON.

While there is no essential difference in the general methods of assaying taught at the School of Mines and those in use at the principal smelters and public assay offices of the West, particularly Colorado and Montana, still there are many minor points in which the practice differs so that a comparison of methods may be of interest.

The wind furnace or crucible furnace is much used at the School of Mines, in fact almost entirely for crucible melting; this furnace is rarely or not at all used in the West for assaying purposes, all work being done in the muffle furnaces. The muffle furnace has the great advantages of cleanliness and neatness. The melting crucible also has a longer life in the muffle furnace than in the wind furnace. This is of considerable advantage in commercial assaying, affording a saving of importance. On the other hand, the size of the charge is limited in the muffle furnace, the muffles in general use not admitting crucibles holding more than a 1 A. T. charge. This necessitates the splitting up of charges on low grade ores or tailings with consequent more labor. The common size of muffle is 18″ long, 12″ wide, 7¾″ high.

In the writer's opinion the wind furnace gives better results on the base metal assays, lead, for instance, than the muffle furnace, notwithstanding the fact that the heat can be better controlled in a muffle furnace.

There is also a difference in the size of the charge in use at the School of Mines and that through the West. There is a tendency in the School to use large charges. This certainly has advantages, decreasing error, but, commercially and economically considered, the results obtained by large charges do not justify the excess of flux used, and when one considers the number of assays made daily at a smelter or in a large assay office, the saving thus made in fluxes amounts to considerable in a year.

At the School of Mines the charge for a crucible assay is rarely less than 1 A. T., and with low-grade ores often more. In the West the charge is almost invariably ½ A. T. for crucible work. For scorification the charge is rarely more than $\frac{1}{10}$ A. T., while at the school it is $\frac{1}{5}$ A. T., and sometimes more.

In the West the gold and silver are determined in almost every case by separate assay, the silver by scorification on $\frac{1}{10}$ A. T., and the gold by crucible assay on ½ A. T., with the addition of silver if the silver contents of the ore is unknown. This silver is added directly to the crucible charge.

This differs from the practice in the School of Mines, where the silver and gold are determined in many cases by one assay, especially if the crucible assay is employed. The practice in the West has the advantage in that scorification is considered better adapted for the determination of silver, except in cases of basic ores and other rare exceptions. The western crucible assay with ½ A. T. also yields accurate results for gold where the ore contains no silver, and where the amount of gold present is small.

In the School of Mines, the three common methods for assaying impure ores for gold are used.

1. Eliminating the volatile impurities by roasting.
2. Oxidizing and slagging off impurities by the use of nitre.
3. Desulphurizing by means of iron nails.

All of these methods are used in the west, but the last, desulphurizing by nails, is by far the most common. At first glance this might seem objectionable on account of the amount of sulphur present, but when it is considered that the charge in most cases is but ½ A. T. it will be seen that unless the ore is very rich in sulphur, the addition of from 3 to 5 nails will accomplish the result desired. Most of the assayers use this method.

The nitre method comes next as regards frequency of use, especially for ores whose approximate composition is known.

The reason for the use of these two methods is apparent, since they require no preliminary treatment, which would take time and labor.

However, ores that are exceedingly rich in sulphur, arsenic and antimony must of necessity be roasted. This requires more care and skill than the other methods, for if not properly conducted as regards heat, considerable inaccuracy may result.

There are three methods for assaying scale ore, commonly used in the west.

1. To grind the ore and scales until the whole passes through a 100 mesh sieve.
2. To take a large weighed sample of ore and grind so as to get

the scales by themselves, then assay the scales and a portion of the pulp separately and combine the results in the proper way.

3. To take a sample of ore, grind to get the scales separately, then dissolve the scales, if copper or silver, in nitric acid or if gold in aqua regia. Evaporate this solution to small bulk and add it to the bulk of the pulp in such a way as to not let it penetrate through to the bottom. Then the pulp is dried and reground and sieved again. A portion of this is taken for essay.

The second method described is the common one in use and the one taught at the School of Mines. The first has the objection, that unless the sample after grinding is mixed very thoroughly and for a long time, it is impossible to get a fair and average sample. In fact the writer has found that it is practically impossible to get assays that check closely by this method.

Ores and mattes that contain copper are always a source of more or less trouble to the assayer and a brief statement as to the methods in use in the west might be of interest.

1. For ores containing copper, not exceeding 15%, the gold is determined by ½ A. T. crucible charges or two ¼ A. T. charges, later combined. Considerable silica is used for fluxing and slagging off the copper. The resulting lead buttons are rescorified to small size and cupelled. Silver is added to the crucible assay as usual. The silver is determined by combining several scorifications.

2. For ores or mattes containing 20% and more of copper the scorification method is employed. The charge, when the ore is heavy in copper is $\frac{1}{20}$ A. T. in preference to $\frac{1}{10}$ A. T. several scorifications are run, usually 3 to 5 on ores, and the resulting buttons rescorified together and cupelled. At the smelters handling copper mattes the standard scorification assay for copper mattes is employed.

3. For ores or mattes rich in copper, the combination or nitric acid method is employed, often to check results on the fire method. The amount of ore taken is usually ½ to 1 A. T. Various modifications have recently been proposed on this method. 1st, to add sulphuric acid in small quantities and evaporate off all nitric acid. Then precipitate a certain quantity of copper by hydrogen sulphide, using this as the collecting agent for the finely disseminated gold in place of lead sulphate. This method is due to L. D. Godshall, T. A. I. M. E., Feb., 1900. 2d, the ordinary

combination assay is conducted entirely in the cold not applying any heat in dissolving the copper or matte. This avoids the solvent action of the combined hot nitric and nitrous acid or gold, nitrous acid being generated in the dissolving of the copper. This method is due to Mr. R. Van Liew (*Eng. and Min. Journal*), April 21 and 28, 1900.

The first two methods for assaying copper bearing material, described above are most commonly used, the last requiring, as a general thing, more time if not more labor than the second.

The gold and silver in zinc bearing ores is determined by scorification, the methods employed being similar to those used for copper ores.

The methods described above are standard throughout the west and represent the best assay practice.

ABSTRACTS.

CURRENT MINING CASES.*

MINING CLAIM—LOCATION NOTICE.

A location notice of a mining claim which fails to give the direction of the initial point, or permanent monument to which it is attempted to tie the location, from the point of discovery, is void, under the statutes of Idaho. Brown *vs.* Levan (Idaho) 46 Pac. Rep. 661, affirmed. Clearwater Short-line Ry. Co. *vs.* San Garde *et al.*, 61 Pac. Rep. (Idaho), 137.

MINES AND MINERALS—INTERSECTING VEINS.

Where two veins, having apexes in different claims, unite in their dip, within the perpendicular extension of the side lines of another claim, the owners of the last claim cannot contest as to the rights in the vein beyond the point of union, since they have no interest in either vein. Roxanna Gold Mining & Tunneling Co. *vs.* Cone *et al.*, 100 Fed. Rep. (U. S.) 168.

CONSTRUCTION OF DEED.

A deed of mineral land described the tract conveyed as a lot situated in a certain town, county and state, "fronting 25 feet on" a certain road, "extending back east 135 feet, more or less, to the gulch, and lying about 25 or 30 feet south from the south side line" of a certain claim. *Held*, in a suit involving its construction, that the description was not so ambiguous as to authorize the submission of the case to the jury. McGuigan *vs.* Hennessy, 61 Pac. Rep. (Mont.), 1.

LIEN FOR MINING SUPPLIES.

Where plaintiff sold mining supplies to defendant from time to time, and monthly bills were rendered therefor, and interest charged thereon, with the understanding that defendant was to be carried till he could make payment by shipping ore, such purchase did not constitute a continuing running account, but each was made under a separate contract, payment for which was due at the end of the month, from which time the 90 days required by Code Civ. Proc. § 2131, for filing of a statement of lien began to run. A. M. Holter Hardware Co. *vs.* Ontario Min. Co. *et al.*, 61 Pac. Rep. (Mont.), 3.

RIGHT OF ENTRY—QUIET ENJOYMENT UNDER LEASE.

In a lease for oil and gas there is an implied covenant of right of entry and quiet enjoyment for the purposes of the lease.

The covenant of quiet enjoyment in a lease for oil or gas, or other purposes, is not broken by the mere fact, alone, that the lessor makes another lease during the term, of the same premises, whether the first lessee be in actual possession or not; the second lessee not entering.

*Prepared for THE SCHOOL OF MINES QUARTERLY by Andrews & Murdoch, Berrien Springs, Michigan.

The covenant for quiet enjoyment implied in a lease for oil is broken by the exclusion by the lessor of the lessee from taking possession for the purposes of the lease or his withholding from him the possession of the land for the purposes of the lease.

Knotts *et. al. vs.* McGregor, 35 S. E. Rep. (W. Va.), 899.

MINES AND MINING—DEED—LANDS CONVEYED—OPTION.

Where testator divided his lands into an upper and a lower tract, devising each to different heirs, and directed that his mines be kept leased, and the profits divided among his heirs, and subsequently the executors deeded the Flint Hill mine, and at the time of testator's death and ever since the only mining done in the lands were in the upper tract, the Flint Hill mine included the mining interest only in the upper tract.

Where a party by written contract bound himself to convey his gold interest with full warranty title, free from all incumbrances, the obligation to be of force for twelve months, if so long be necessary, only an option for twelve months was given and if at the expiration of that time, either party could not carry out the terms of the agreement, he was released therefrom.

Love *vs.* Love *et. al.*, 35 S. E. Rep. (S. C.), 398.

GRANT OF OIL AND MINERALS.

The owner of land granted to another the oil, gas and other minerals underlying the land, on condition that the grantor should have a certain share of the oil, gas and minerals so mined. The grant provided that, if no well was completed by the grantee within ninety days from and after the date of the grant, the same should be null and void, unless the grantee should pay the grantor a certain rental for each year the completion of the well was delayed. It was further stipulated that the grantee should have the privilege of surrendering the lease at any time by paying the rental on the land to the time of surrender. *Held*, since it was optional with the grantee as to whether or not anything should ever be done by him, and as no well was made, there was no obligation to pay any rent, or to make compensation for oil or gas. Brooks *vs.* Kunkle *et. al.*, 57 N. E. Rep. (Ind.), 260.

CONTRACT—PURCHASE OF MINING PROPERTY—SEPARATE INTERESTS IN REALTY.

A contract by plaintiff to sell, and by defendants' predecessors in interest to buy, certain mining property, which contract is personal, and does not, in terms, run to heirs and assigns, and under which the prospective grantees, although given possession, could neither sell nor assign, without grantor's consent, until they had become entitled to a deed by performance of certain conditions, one of which was to pay grantor a certain sum out of the property, is a mere option to purchase, with a license to extract ore, and not a covenant running with the land.

The surface of mineral lands may be owned by one person, and the mineral underneath by another, each with an indefeasible title. When so owned, they constitute separate corporeal hereditaments, with all the incidents of separate ownership, and the surface land may be partitioned the same as where there is no mineral under it.

Smith *vs.* Jones *et al.*, 60 Pac. Rep. (Utah), 1104.

SUIT FOR INSTALLMENTS DUE—REASONABLE METHODS OF MINING.

Where eight suits for instalments due on a mining contract were consolidated, and a demurrer sustained to the complaints therein, and plaintiff subsequently filed an amended complaint for all such instalments he was not entitled to allege error in the sustaining of such demurrer.

Where defendant leased a mine, agreeing to pay a royalty for all coal in the seam which could be reasonably mined, and at the expiration of the lease to pay for all coal in the seam whether mined or not, on terminating the contract in the absence of a stipulated safe mode for mining the coal, defendant was only liable for such coal remaining in the mine as could be mined by the modes usually adopted in that locality with reasonable safety, and was not liable for coal rendered unmerchantable from causes which could not be prevented by prudent management.

Gaines *vs.* Virginia & A. Coal Co., 27 So. Rep. (Ala.), 477.

CULM OR MINE WASTE—EXCESSIVE JUDGMENT.

Defendant leased of plantiff all the coal contained in or under certain lands, and was to pay for coal mined and taken out, at a certain royalty per ton, on clean, merchantable coal, "exclusive of culm or mine waste which would pass through a one-half inch mesh," and that defendant should pay for 10,000 tons yearly, whether that amount was taken out or not, and interest on sums representing yearly deficiencies below 20,000 tons until that amount was reached. *Held*, that the provision regarding culm was to be construed as permitting defendant to mine culm, or not, as it chose, but that if it did mine and appropriate culm, it was liable for royalties thereon.

Where plaintiff recovers a judgment for the full value of certain coal mined by her lessee under the lease, and it is held, on appeal by the lessee, that she is only entitled to recover royalties thereon, plaintiff will be given the option of either remitting so much of the judgment as is in excess of such royalties, or submitting to a new trial.

Genet *vs.* President, etc., of Delaware & H. Canal Co., 57 N. E. Rep. (N. Y.), 297.

VENDOR AND PURCHASER—CONSTRUCTION OF CONTRACT.

A contract for the sale of coal lands provided that the purchaser was to have at least 500 acres of mineable coal, and for any shortage from that quantity he should be allowed a credit on an installment of purchase money to become due in one year. It further provided that any claim for shortage should be made within three months, after which the vendor should have the right to have a survey made. Within the time fixed the purchaser made a claim to a shortage of sixteen acres, which claim, after having a survey made, the vendor denied, and while matters were in that condition the payment became due. A partial payment was made, and the vendor gave a receipt extending the time for future payments, and providing that, "if there shall be any shortage in the acreage of coal, the amount to be deducted on account thereof" should be deducted from a subsequent payment, and that "the amount of said shortage is to be ascertained within six months." *Held*, that under such agreements, construed together, the purchaser was not limited in his claim of shortage to

the sixteen acres of his original claim, but that the second agreement contemplated the allowance of "any shortage" ascertained within the six months. Rainey *vs.* Hogsett *et. al.*, 100 Fed. Rep. (U. S.), 207.

STATUTE AGAINST WASTE OF OIL AND GAS—OWNERSHIP OF OIL OR GAS.

The restriction on the waste of gas and oil by owners of land, made by Ind., Acts, 1893, p. 300, which provides that it shall be unlawful to permit the flow of gas or oil from a well to escape into the open air, without being confined, the well or proper pipes or other safe receptacle, for more than two days after the gas or oil shall have been struck in the well, does not take the private property of the owners of the land without adequate compensation, and therefore without due process of law, since the owner of the surface has no property right in the gas or oil until he has actually reduced it to possession, or, if he has any property right therein, it is a right in common with the coequal right of other land owners to take from the common source of supply, and therefore subject to the legislative power to prevent a destruction of the common property by one of the common owners.

The doctrine that a land owner, although entitled to bore wells for natural gas and oil, has no title to those substances as owner until they are actually reduced by him to possession, is settled as a rule of property in the State of Indiana.

Ohio Oil Company, plff. in Err. *vs.* State of Indiana, 20 Sup. Ct. Rep. (U. S.), 576.

SALE OF OIL RIGHTS—BREACH OF CONTRACT.

S. purchased of A. seven-eights of the undivided one-half interest of A , in the oil and gas in and under 243 acres of land, and paid $300 cash therefor; and, as part of the terms and conditions of sale, S. was to begin to operate, mine, and bore for oil and gas within and under said tract of land, free of cost to A., within 60 days, and complete one well thereon in one year, unavoidable delay and accidents excepted; and if oil be found thereon in paying quantities, then, after the first said well was completed thereon, S. should immediately commence and drill other wells thereon as should seem necessary to protect the oil and gas in and under the said tract of land, and should also deliver as royalty to the credit of A., free of cost to him, the one-half of the one-eighth of all the oil produced and saved from the said land, in pipe lines or tanks, and pay to him the one-half of $300 per year for the gas from each and every well drilled thereon, producing gas, the product from which should be marketed. *Held*, that the remedy for violation of said conditions of the sale is not by way of forfeiture of the rights of S. to bore or drill for oil on the land or any part of it, but by an action or proceeding for damages caused by such breach. Ammons *et al. vs.* South Penn Oil Co., 35 S. E. Rep. (W. Va.), 1004.

MASTER AND SERVANT—INJURY OF SERVANT—SAFE PLACE TO WORK.

A mining company, which erects a stull or platform across a narrow and dark fissure in its mine, 70 feet from the bottom, on which its employés are required to work, is bound to the exercise of reasonable care to see that the timbers are of adequate strength and number, and securely fastened, to render it a safe place on which to work.

Plaintiff's husband was killed, with other workmen, by the breaking and falling of a stull in defendant's mine, on which he was working in stoping ore 70 feet from the bottom. The stull was erected by defendant by placing lagging on timbers running across a fissure in which it was built, and supported in its sides and was intended to be of sufficient strength to sustain the weight of 20 feet of earth and rock upon its top, although there was but 9 feet in depth upon it when it broke and fell. *Held*, that the fact of its falling under such circumstances was in itself evidence from which a jury might infer that it had not been properly constructed, and that, when taken in connection with the fact that a number of the cross timbers were broken in the middle, and with the testimony of two competent witnesses, who stated their opinions that the timbers were insufficient in strength or number to carry the load placed upon them, it could not be held, as matter of law, that defendant was not negligent, but the question was one for the jury.

Westland *vs.* Gold Coin Mines Co., 101 Fed. Rep. (U. S.), 59.

STATUTORY INSPECTION—WILLFUL VIOLATION.

Where plaintiff alleged that his injuries were the result of the willful violation by his employer of certain laws relating to the employer's duty to examine the condition of the mines, where plaintiff was employed and injured, an instruction that, if there was such willful violation, plaintiff was relieved from showing that he was in the exercise of ordinary care, was proper.

Where the report of an examination of defendant's mine did not show that all the conditions were safe, and plaintiff gave defendant notice of the dangerous condition of an entry, and was permitted to enter the mine to work, and was injured, there was evidence to support an instruction based on willful violation of Mining Act, § 4, providing that all mines shall be examined every morning, and that no one shall be permitted to enter until the conditions are reported to be safe.

Where an examination of defendant's mine was made, but the record did not show that all the conditions were safe, and plaintiff was permitted to enter the mine to work, and was injured, the fact that he did not examine the record did not prevent him from charging defendant with a willful violation of Mining Act, § 4, providing that all mines shall be examined every morning, and that no one shall be permitted to enter until all the conditions are reported to be safe, since plaintiff was entitled to assume that defendant was complying with its statutory duties.

Pawnee Coal Co. *vs.* Royce, 56 N. E. Rep. (Ill.), 621.

MINES AND MINERALS—QUIETING TITLE.

Though a void tax deed of mineral land is admissible to show that the grantee entered under a written instrument, in order to bring him within the provisions of Code Civ. Proc. § 323, declaring what constitutes adverse possession under a written instrument, it was harmless error to exclude it in an action brought by him to quiet title, where it was shown that he had not been in exclusive possession of the land during the requisite period.

Where a witness on direct examination stated the boundaries of a mining claim, and that the notice of location posted by him for the locator

gave the same boundaries, it was not improper to require him to state on cross-examination whether the notice also contained a statement that the notice was made for the purpose of re-establishing the boundaries.

Where plaintiff in an action to quiet title to mineral land claimed exclusive adverse possession from the date of his location, and the evidence showed that defendant had purchased an interest from prior locators, and had continued in possession with them until they leased it to a third party for a term of years, which expired after plaintiff's entry, the lease was competent evidence to show that defendant was in possession by his lessee when plaintiff was claiming exclusive possession.

In an action to quiet tit e to mineral land, where a conveyance from the original locators to defendant, under which he claimed, was shown to have been lost, and that he had never read it, it was not prejudicial error to allow him to testify as to when the instrument was made, and when he began work on the claim.

Simmons *vs.* McCarthy, 60 Pac. Rep. (Cal.), 1037.

WHAT CONSTITUTES CARRYING ON BUSINESS IN A STATE—EFFECT OF MISTAKE AS TO DIRECTION OF LODE.

A single contract made by a corporation owning mining ground in a a territory, by which it employs and agrees to pay a second party to exploit and develop the property, does not constitute a carrying on of business in the territory by the corporation, within the meaning of a statute requiring foreign corporations carrying on business within the territory to file copies of their articles of incorporation, and providing that every act done by them prior to the filing thereof shall be void; and such statute does not affect the validity of the contract.

Under the rule that where a lode mining claim is located across, instead of along, the vein, the original side lines become end lines, and the end lines side lines, the owner is entitled to all the rights with reference to the new side lines that he would have had if they had originally been located as such, including the right to follow the dip of a vein having its apex within the surface boundaries of his claim beyond the vertical plane passing through such lines.

Defendant, the owner of a mine, contracted with plaintiff, which owned an adjoining claim, to extend its workings into such claim, for a stipulated price, for the purpose of exploiting and developing the prop erty, and agreed that, should any marketable ore be taken therefrom in the course of such development it would sell the same, and account to plaintiff for the proceeds. *Held*, that defendant was not estopped by such contract from claiming the proceeds of ore so removed and sold as its own, where in making the development, it discovered that the vein from which it took such ore had its apex within the lines of its own claim, and the ore was, therefore, its own property.

Empire Milling & Mining Co. *vs.* Tombstone Mill & Mining Co., 100 Fed. Rep. (U. S.), 910.

OPERATION OF MINE BY CO-TENANTS—CO-TENANT WRONGFULLY WORKING MINE.

Code Civ. Proc. 1895, § 592, authorizes a tenant in common to sue for an injury to the property by a co-tenant; and Laws 1899, p. 134,

amending the same, declares that nothing contained therein shall prevent the occupancy and enjoyment of mining property by co-tenants, or the operation of the same, subject to accounting to a nonjoining co-tenant for net profits, nor prevent such joint co-tenant from receiving his proportionate share of all ores on the dump, on payment or tender of the cost of mining the same. *Held*, that a co-tenant not joining in the operation of a mine, and suing for damages for the removal of ore therefrom through another mine, owned by his tenant in common, to which plaintiff had no right of access, was entitled to an injunction pendente lite to restrain such removal, though defendant offered to account for ore extracted therefrom.

Laws 1899, p. 134, authorizes a nonjoining co-tenant of mining property to recover his share of the net profits of the mine, or his proportionate share of all ores on the dump, on payment or tender of the costs of mining the same in a miner-like manner. *Held*, that where defendant, a co-tenant, wrongfully worked a mine through a shaft from another mine, in which plaintiff had no interest and to which he had no right of access, plaintiff was entitled to an injunction pendente lite, restraining defendant from continuing to work such mine, though he failed to tender his proportionate share of the cost of mining the ore extracted therefrom, since such tender was excused by plaintiff's inability to ascertain what ores it was entitled to in order to estimate the amount of such tender.

Butte & B. Consol. Min. Co. *vs.* Montana Ore-Purchasing Co. *et al.*, 60 Pac. Rep. (Mont.), 1039.

Construction of Notice of Location.

In construing a notice of location of a mining claim there is no rule of necessity, such as exists in the construction of deeds, which requires that the terms "easterly" and "westerly," used without qualifying language, shall denote due east and west.

A notice of location of a mining claim, which gives the course of the location as running a certain distance in a westerly and easterly direction from the point of discovery, until the boundaries are definitely located by monuments, reserves from entry by subsequent locators the surface area which might be included in any location so made that if a line be drawn lengthwise through the center of the claim from the west center end thereof through the point of discovery to the east center end thereof said line will lie between east, 45° north, and east, 45° south, from the point of discovery.

If a locator of a mining claim, when posting his notice of location, in addition to giving the general course of his vein, places monuments at the center of each end line thereof, thus giving definite notice to subsequent locators as to the meaning of his notice, he is bound thereby, and cannot thereafter, during the time prescribed by law for perfecting his location, change the course of his location to the prejudice of intervening rights.

Where a notice of location of a mining claim as posted did not definitely locate the eastern end thereof, it was proper for the court to refuse to charge that, if the locator changed the easterly end of the claim from where it was first located by his location notice to a point 800 feet northerly, as fixed by the location certificate, such change was void, as it was not a substantial compliance with the notice.

Wiltsee *vs.* King of Arizona Min. & Mill Co., 60 Pac. Rep. (Ariz.).

JOINT OWNERS—LOSS OF PROFITS.

In an action by a lessee of the owner of an undivided third of a mine to recover damages from the owner of the remaining interest therein for his refusal to allow him to work the mine the fact that all the evidence as to the amount of ore mined prior and subsequent to the term of plaintiff's lease was stricken out did not entitled defendant to a nonsuit, where it appeared that ore was mined by defendant during such term at a profit, and defendant failed to deny an allegation in the complaint that he had extracted ore of a certain value.

In an action by a lessee of the owner of an undivided third of a mine to recover against the owner of the remaining interest for his refusal to allow him to work the mine, defendant's contention that plaintiff could not recover for loss of profits he might reasonably expect to have derived therefrom was without merit; it appearing that the mine had been worked previous and subsequent to the term of the lease at a profit, and had yielded a desirable product.

Where defendant's right to a partition of a mining claim, which he owned as a co-tenant with plaintiff's lessor, was not involved in an action, to recover damages for defendant's refusal to allow him to work the mine under a lease of an undivided third interest of the owners, an objection that the lease was void because it would prejudice defendant's right to a partition will not be reviewed on appeal.

Where the lessee of an undivided interest in a mine sued the lessor's co-tenant for refusal to allow him to work the mine during the term of a lease which had expired, such action was not to recover for the loss of prospective profits, but for damages thus accrued.

Paul *vs.* Cragnaz, 60 Pac. Rep. (Nev.), 983.

MASTER AND SERVANT—MASTER'S VIOLATION OF STATUTORY REQUIREMENTS.

Hurd's Rev. St. 1889, c. 93, § 6, provides that a sufficient light shall be furnished at the top of every shaft of a mine to insure the safety of persons getting on or off the cage; and section 8 requires that the top of every shaft shall be securely fenced by gates properly protecting such shaft; and section 14 provides that any injury arising from failure to comply with the provisions of the act shall give a cause of action. *Held*, that where a mine owner had erected above the opening of a shaft an unenclosed framework of timber, supporting a structure called a "tipple house," to which the cage could be hoisted, and through which the day shift entered and left the shaft, but it was customary to let off the night shift at the surface of the ground, and plaintiff's intestate, being one of the night shift, and endeavoring to alight, fell into the shaft and was killed (it being dark at the surface, and there being then no fence there), it was proper to submit to the jury the questions whether the surface or the tipple house was the top of the shaft, within the meaning of section 8, whether the proximate cause of the injury was the absence of a light.

When an employé of a mine, endeavoring to alight from a cage at the surface opening of the shaft, fell into the shaft and was killed, the opening of the shaft being enveloped in darkness by reason of no sufficient light being furnished, as required by Hurd's Rev. St. 1889, c. 93, § 6, contributory negligence of deceased could be no defense to the mine

owner in an action for damages for deceased's death, under chapter 93, § 14 providing that any injury from failure to comply with the provisions of the act shall give a cause of action.

Hurd's Rev. St. 1889, c. 93, § 6, provides that a sufficient light shall be furnished at the top of every shaft of a mine to insure the safety of persons getting on or off the cage; section 8 requires the top of every shaft to be securely fenced, to protect the entrance to the shaft, and section 14 declares that, for any injury to person or property by willful failure to comply with the provisions of the act, a cause of action shall accrue. *Held* that, where a declaration against a mining company alleged that plaintiff's intestate came to his death by defendant's willful omission to comply with section 6 and 8, it was proper to refuse to allow officers of defendant to testify that they intended to comply with the statute in good faith, since the word "willful," as employed in the declaration, did not involve a charge of wrongful intent, but only that the omissions were conscious acts of the mind, and not from mere inadvertence.

Odin Coal Co. *vs.* Denman, 57 N. E. Rep. (Ill.), 192.

ACCOUNTING FOR GRUB STAKE—MINING PARTNERSHIP.

A complaint alleged that plaintiffs furnished defendant means to go to Alaska to prospect for mining claims, and that defendant agreed that plaintiffs should have an undivided one-half of any discovered, together with one-half of net proceeds of minerals mined by defendant from such claims after one year from the date of the agreement. The complaint further alleged that defendant discovered certain mining claims, and had sold some of them; that said claims were worth a sum stated, and that defendant had mined therefrom minerals worth a certain sum; that defendant refused to convey any part of said claims to plaintiffs, or to account to him for them. The complaint prayed for an accounting as to minerals mined and money received, and that defendant be required to convey to plaintiffs an undivided one half interest in any claims owned by him, and be restrained from conveying any of said mining claims pending the action. *Held*, an equitable action.

Civ. Code, § 2511, provides that a mining partnership exists between two or more persons who own or acquire a mining claim for the purpose of working it it, and actually engage in working the same. Civ. Code, § 1395, defines a partnership to be the association of two or more persons to carry on business together and divide the profits. Plaintiffs furnished defendant means with which to go to Alaska to locate mining claims. Defendant agreed that plaintiffs should have an undivided one-half of all mining claims located together with one-half net proceeds of all minerals mined therefrom after the first year. It was also agreed that, in case defendant discovered any valuable claims, he should notify plaintiffs, and they should thereupon go to the place where defendant had located said claims, and assist in working them, they to furnish one-half the labor and expense thereof; and said plaintiffs to be owners of an undivided one-half of any claims so located, and to have one-half the minerals mined therefrom. *Held*, that though the contract may have contemplated the formation in the future of a mining partnership, it did not constitute a co-partnership which commenced on defendant's starting for Alaska, so as to entitle plaintiffs to an accounting, where defendant refused to let plaintiffs work claim discovered by him.

Civ. Code, § 3391, provides that a specific performance cannot be enforced against a party to a contract if he has not received an adequate consideration for the contract, or it is not as to him just and reasonable. A complaint alleged that plaintiffs furnished defendant with $50 as a grub stake, and that he agreed to go to Alaska and locate mining claims under an agreement that plaintiffs should have one-half of all claims so located, and that the defendant did locate certain claims of great value, and prayed that he be decreed to convey an undivided one-half interest therein to plaintiffs. *Held*, that complaint, in the absence of any allegations as to what the claims had cost defendant, was demurrable on the ground that the consideration was inadequate.

In an action by one who has furnished another money as a grub stake to go to Alaska to locate mining claims, for specific performance of an agreement that the party furnishing the funds should be entitled to one-half the claims located, where the expense of the trip is not shown the court will take judicial notice that $50 is not an adequate consideration to entitle plaintiffs to specific performance of a contract giving him one-half the fruits of so toilsome and expensive a journey and the expense of locating claims.

Prince *et. al. vs.* Lamb *et. al.*, 60 Pac. Rep. (Cal.), 689.

BOOK REVIEWS.

The Calculations of Analytical Chemistry. By EDMUND H. MILLER, Ph.D., Instructor in Analytical Chemistry and Assaying in Columbia University. New York, The Macmillan Co., 1900. 8vo. 183 pages. $1.50 net.

The original meaning of the word stoichiometry, "The measure of elements or component parts," is capable of broad application. The definition usually given in the dictionaries, "The mathematics of chemistry," is somewhat vague. The term stoichiometry is usually assumed to cover only such calculations as involve the equivalents or atomic masses of the chemical elements. If strictly confined to this, many of the mathematical operations necessary in laboratory work would not be included, *e. g.*, specific gravities, gaseous volumes as affected by temperature and pressure, calorimetric and electrical calculations, etc.

The result is that for books of instruction in laboratory calculations the name stoichiometry has been usually avoided in the title because too limiting. The book before us has no doubt received its title with that point in view.

The arrangement is quite different from that of most books of the kind. The first chapter describes briefly some easily applied methods for determining a few chemical equivalents, from which the step to a clear conception of the significance of atomic mass (or weight) is easy and natural.

Presented in this way, the calculation of formulæ from percentage, and *after that* of percentage from formulæ does not appear to be so radical a reversal of the ordinary sequence, as it might otherwise seem.

Among other features, the calculation and use of factor weights, and also estimation of the excess necessary to affect an indicator (in volumetric analysis) are given an importance well merited, but not usually accorded to these points in books of the kind.

Under volumetric analysis, reference is inevitably made to the differences in the interpretation of the term "normal solution." The definition given in Sutton's volumetric analysis, and consequently adopted by many (including the book under consideration) is that a normal solution contains per litre the *hydrogen equivalent* in grammes of the active constituent. The definition adopted by Muir and some others is that it contains per litre the *molecular weight* in grammes of the substance. Either definition involves certain inconveniences, and also apparent inconsistencies. In our opinion the last mentioned is the simpler and more scientific definition.

Nevertheless, in writing in chemical language (or any other language for that matter) it is eminently desirable that one's terms should have a definite meaning, and it is greatly to be regretted that any such difference in interpretation should have arisen.

After the discussion of problems belonging more particularly under the head of Stoichiometry, Gravities, Gaseous Volumes, and Calorimetric and Electrical Calculations are taken up. All of the points are presented clearly, and in a manner calculated to hold the interest of the student. One exception, however, should be noted to this—the distinction between Density and Specific Gravity is not clearly made.

The book had no doubt been prepared to fit into a certain plan of instruction, but it is likely to find a more extended use, the arrangement of the matter having many advantages over that of most books of its kind, and will be appreciated by many teachers of the subject.

E. W.

A Text-book of Physics. By W. WASTON, A.R., C.S., Bs.C. Assistant Professor of Physics at the Royal College of Science. London and New York, Longmans Green & Co., 1899.

It is a genuine satisfaction to review a book which so much of good can be said, as is the case with the above.

Textbooks of Physics are published "every little while" like "The Philistine," but they have generally so little to recommend them, that the most one can do is to remain silent.

Mr. Watson has succeeded in putting together a single volume of moderate size, which contains a large quantity of information not found except in the large treatises of several volumes, leaving out little or nothing essential and yet perfectly intelligible to any one who is familiar with even the rudiments of physics and mathematics.

Nothing human is perfect and even if it were, imperfect individuals would have some fault to find with it; hence I may criticise some minor points in the book.

It would be unfair to criticise the use of the "imperial print" in an English book, and yet it emphasizes the pressing necessity of dropping all those antiquated units and putting the first nations of the world at least in the same class with the others on the subject of metrology.

Such subjects as oblique impact, rolling friction, the gravitation constant, dimensions of molecules, etc., are unusual in one volume text-book and yet they were very well treated.

The pendulum in all its forms are very clearly presented and even the conditions of isochronism and reduction to infinitesimal arc.

The whole subject of heat is exhaustively and well treated, including the relations of pressure, volume and temperature, calorimetry, conduction of solids, liquids and gases, heat engines, and even the thermodynamics and methods of the production of liquefied air and other similar gases; and yet, while referring extensively to the secular changes in mercurial thermometers, no mention is made of Jena glass and the improvements in thermometry acomplished therewith.

Under sound the general facts of wave motions in the medium as well as on the surface of a liquid are particularly well illustrated by diagrams and photographs; even Huygens' principles and constructions are given. A small error occurs, however, in stating German standard pitch as $a = 400$ vib. per sec. It should be $a = 440$ vib. per sec., and of course $a = 460$ vib. per sec. may be English concert pitch, but the best American authorities use $a = 437$ vib. per sec.

Moreover, it is to be hoped that we may some day come to distinguish properly between a *note* and a *tone*, at least in science.

The question of combination tones, quality, dissonance, resonance, etc., are well brought out, but why was it necessary to give Ganot's Physics credit for several indifferent cuts that are not even original in that text-book.

The question of caustic curves in mirrors is well developed, as well as many minor points in refraction of light, including the Michelson interferometer, and yet double refraction and polarization get only two pages, and the saccharimeter ten lines.

Under terrestrial magnetism the isogonals and isoclinals for England for 1891 are given. It is to be hoped that those for 1900 were available.

In electrostatics the relations of lines, and tubes of force, and equipotential surfaces are clearly illustrated, also the matter of potential, and energy in the ether, hysteresis, certain ionic relations, Verdet's constants, and even the Zeeman effect.

A very satisfactory attempt to popularize the electromagnetic theory of light deserves mention, and especially the chapter on the enegetics of the Voltaic cell, where its thermochemical treatment and calculations are given in the most satisfactory manner yet presented.

I consider it the best text-book of physics of its size yet published, and heartily recommend it to every student and teacher.

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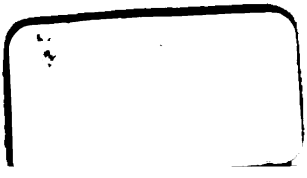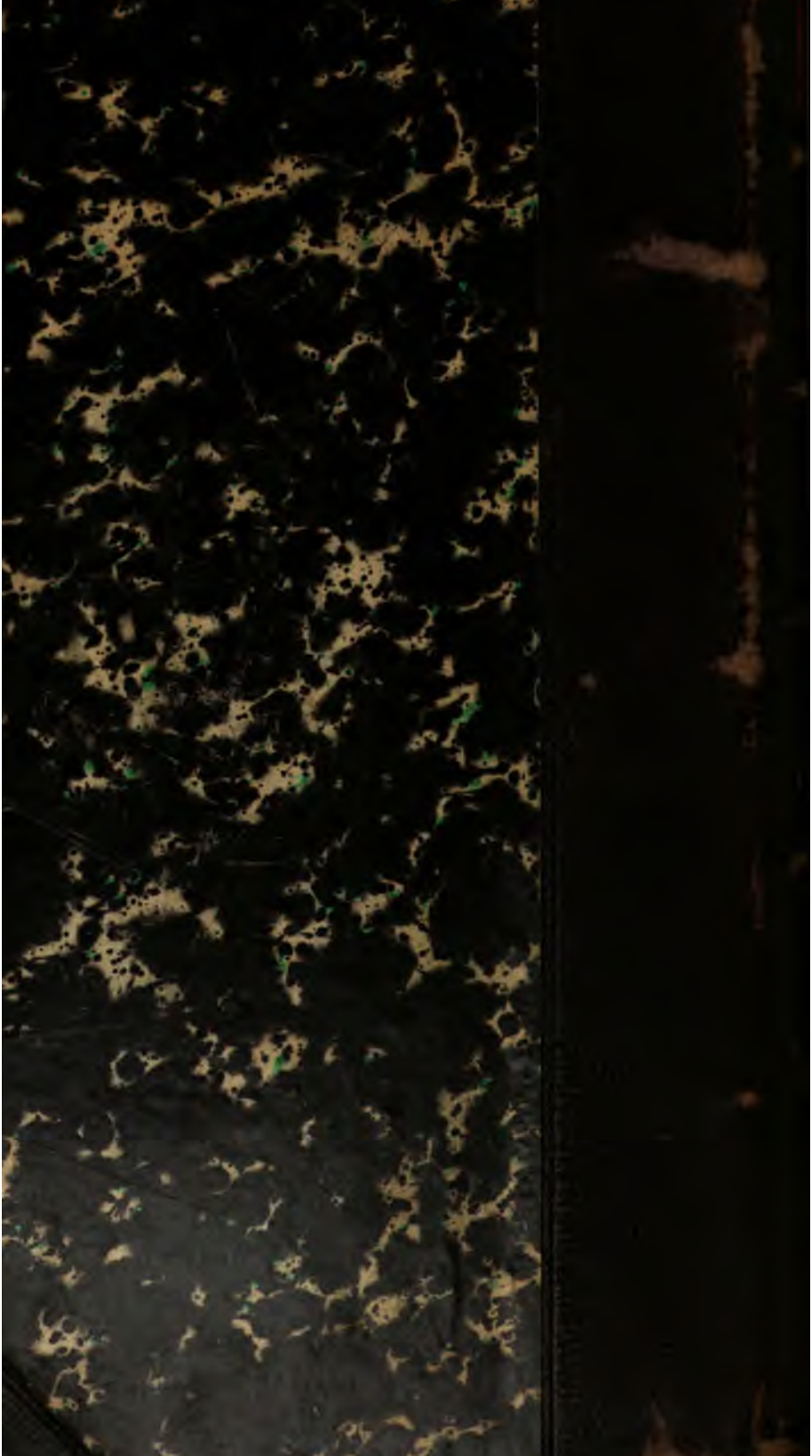
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